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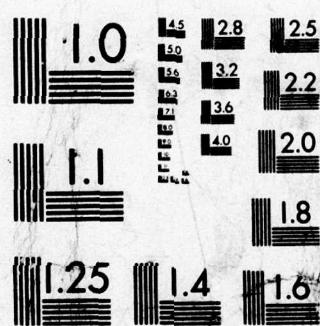

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ARMY AIR MOBILITY R&D LABORATORY

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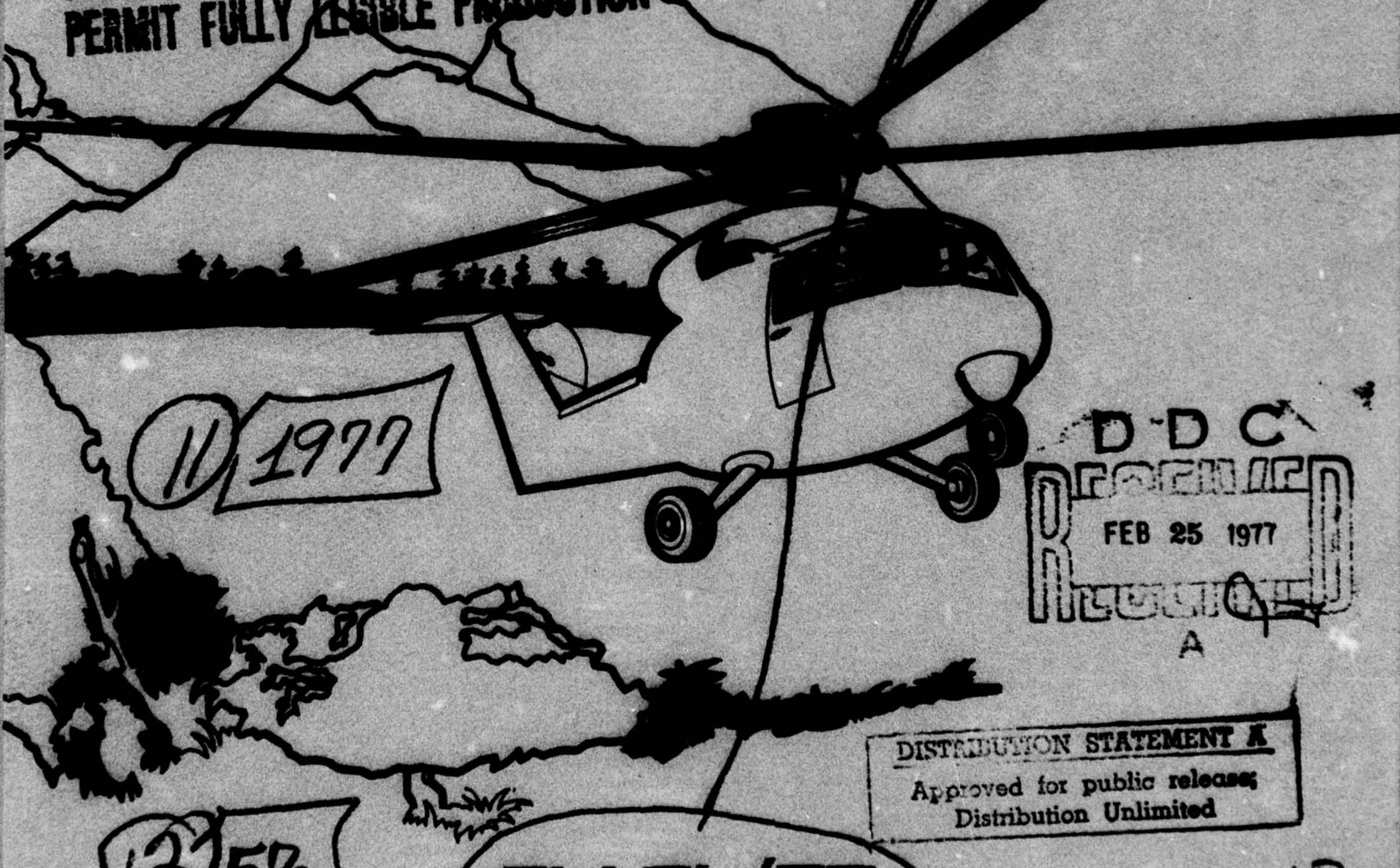
Annual Report

AMRDL



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PREFACE

Dr. Richard M. Carlson, Director

US Army Air Mobility Research and Development Laboratory

The history of Army aviation research and development began in 1945 under the direction of the Ordnance Corps. The Transportation Corps "inherited" aviation from the Ordnance Corps about 1952 but was not allowed to establish "unilateral" aeronautical facilities. A Transportation Corps Aviation Field Office (TAFO) was established at Wright Field to handle Army aviation business, both procurement and R&D. TAFO was responsible for aircraft development and joint Army/Air Force projects such as the XV-1, XV-2, XV-3, and the procurement of helicopters; H-13, H-19, H-21, H-23, etc. The Navy-developed helicopters, such as the H-34 and H-37, were procured through the USAF with the Army paying a large amount of the development costs.

The Army/Air Force arrangement was not entirely satisfactory as the Army was committing large amounts of research dollars into programs that were not considered to fulfill any existing Army aviation requirement. Based on this, the Army was authorized to conduct "research to determine requirements." This initiated the Army's test bed program and was the first instance of the Army; specifically TRADS, TRADCOM, TRECOM, AVLABS, getting into aircraft R&D. In 1962, the material development functions of the Army's Technical Services, including Aviation, were merged into what is now US Army Materiel Development and Readiness Command. TRECOM was transferred into AVSCOM when AVSCOM was established as the Aviation Command at St. Louis. At this time studies were also initiated by the Director of Army Research on how to improve the Army's aviation capability.

The AVLABS and its predecessors possessed only limited in-house research facilities. Although productive of many significant accomplishments, it was necessarily largely contractual in nature and could not fully provide needed in-house bench-level research effort. Therefore, the AMC (now DARCOM) sought a means to obtain the needed effort and to bolster low-speed aeronautical research which was sagging, due to priorities placed on high-speed and space flight. This was accomplished by AMC, to a limited extent in 1965, by the establishment of the Army Aeronautical Research Laboratory under a unique interagency agreement for joint participation in research with the National Aeronautics and Space Administration at Ames Research Center.

In 1968, the Army assessed its total requirement for aviation research and development under the auspices of the Carlson Committee. Their report recognized the need for further development on in-house capability and unification of all laboratory work under a single agency. As a result, a 1970 reorganization of Army aviation research facilities took place and the US Army Air Mobility Research and Development Laboratory was established under AVSCOM and AMC. The Laboratory consists of four Directorates under a single Headquarters. The former AVLABS is now the Eustis Directorate and the former Aeronautical Research Laboratory is now the Ames Directorate. New directorates were formed under expansion of the Army/NASA Agreement which are known as the Langley Directorate and the Lewis Directorate.

The AMRDL (see Organizational Chart, Figure 1, opposite page 1) has the fundamental objective of demonstrating aviation technology needed to provide simple, rugged, reliable air-mobility equipment of superior performance, which the typical Army man can operate and maintain. To accomplish this objective, the AMRDL pursues an orderly and timely sequence of activities in a broadly based, multidisciplinary program directed toward the establishment and growth of a technological base for future development of Army airmobile systems and products. The AMRDL serves both the specific and long-range research and development needs of Army aviation. The basic concept is an in-house center of professional excellence operated by and for the Army and staffed with both civil and military personnel.

The Headquarters, AMRDL, is located at the Ames Research Center, Moffett Field, California. Despite geographic dispersion of its elements, it is one laboratory carrying out a single unified program. A unique feature of the Laboratory is the interagency relationship of three of its directorates with the NASA at Ames, Langley, and Lewis Research Centers. This feature not only conserves the resources of both agencies in the performance of research and common interest to each, but also provides the Army with direct access to the facilities and professional expertise of NASA for application to specific Army requirements. NASA benefits further by direct exposure to user requirements of the Army. This cooperative effort is most effective to both agencies in the current environment of dwindling resources, since both manpower and dollar resources are pooled for appropriate joint research efforts. Through its special relationship with the NASA, the Laboratory's achievements have contributed to civilian interests in rotary wing aeronautics as well.

The AMRDL is a highly valuable research complex, staffed by 564 civilian employees and 26 military personnel. The Laboratory looks forward to a period of continuing development and increasing productivity.

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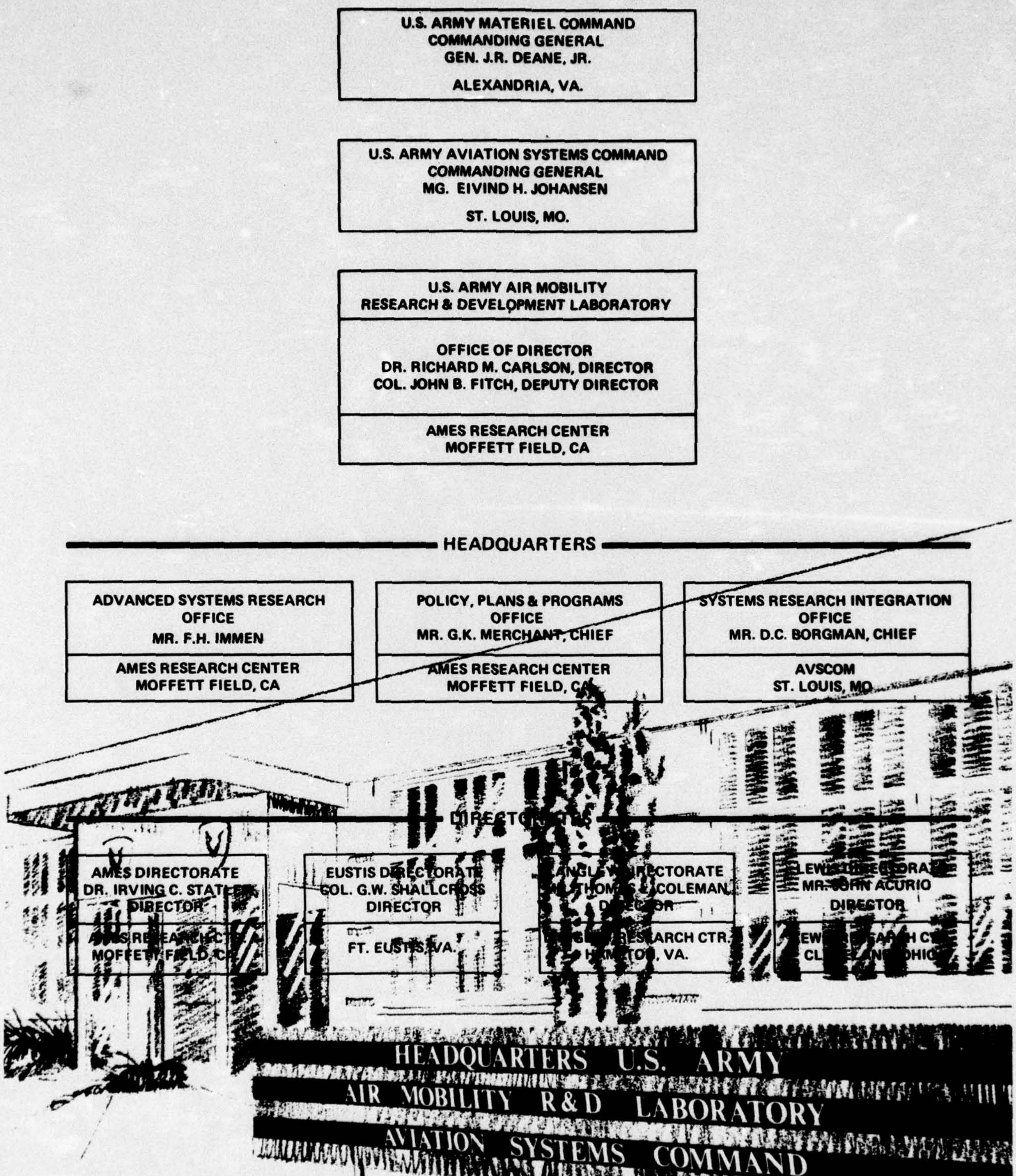

Figure 1. US Army Airmobility R&D Laboratory organizational chart.

US ARMY AIR MOBILITY R&D LABORATORY
–FY76/7T REPORT OF ACTIVITIES–

INTRODUCTION

The US Army Air Mobility R&D Laboratory (AMRDL) is the Research and Development Laboratory of the US Army Aviation Systems Command (AVSCOM). The capabilities of its staff of research, engineering, and support personnel span the sciences, disciplines, and technologies of Army aviation. Its organization is represented by the chart (figure 1) located on the opposite page.

The Laboratory is charged with the following mission elements:

- Plan, develop, manage, and execute for the AVSCOM the research and exploratory development programs and the advanced development program through demonstration of technology to provide a strong technical base for future development of superior airmobile systems.
- Manage and direct on a task basis, as assigned by Commander, AVSCOM, tasks in advanced and engineering development subsequent to demonstration of technology.
- Maintain cognizance of, and provide consultative support for, advanced development subsequent to demonstration of technology, engineering development, operational development, and test for all Army airmobile systems.
- Provide technical consultation and independent risk assessment to Commander, AVSCOM for systems and components under development.

The Laboratory strives for improvement in both the development of a technology base and the support to system developers. By establishing and maintaining broad capabilities, the Laboratory has been able to achieve multidisciplinary capabilities to respond to urgent technical requirements of both the immediate and long-range needs of Army aviation, and has earned an international reputation for the outstanding achievements and abilities of its staff. The honors and awards received by staff members and the contributions they have made to the world's scientific literature during 1976 are listed in this report. Overviews are given for this year's accomplishments in the various technical areas to illustrate the scope and purposes of the Laboratory's research and development programs.

During the FY76/7T period, AMRDL has operated under a continuing climate of austerity in terms of funds. Realistic assessment of the Laboratory goals relative to the available resources requires a continual adaptation of the Laboratory's program structure to assure short- and long-range research and development efforts are best directed to activities which will achieve the Army objectives for which AVSCOM is responsible.

The FY76/7T Annual Laboratory Posture Report is prepared in response to the US Army Materiel Development and Readiness Command instructions and guidance contained in letters, DRCLDC, dated 10 May 1976 and 23 July 1976.

KEY EXECUTIVE ITEMS

NOTEWORTHY MANAGEMENT ITEMS

The most unique aspect of the management of AMRDL lies in its ability to operate as a single operating entity although its four separate Directorates are geographically dispersed from coast to coast. The Laboratory operates under a single Director and is managed as a unit. This unity of management allows for full responsiveness to the needs of the various program managers and it allows the entire capability of the Laboratory to be quickly brought to bear on any specific objective.

For example, AMRDL has continued to provide quick technical and management support response to the Remotely Piloted Vehicle (RPV) Weapons System Manager in a number of areas. In particular, the Laboratory has expedited several RPV program procurements, undertaken several risk assessments and program reviews, presented briefings to Army management, and coordinated the RPV program with industry and other military services. The Eustis Directorate of AMRDL is now the lead laboratory for mini-RPV propulsion systems within the military community and has hosted two triservice conferences. The AQUILA is the primary RPV program within the Army and also represents the first time a Letter of Agreement was utilized as a management structure between the US Army Materiel Development and Readiness Command and the US Army Training and Doctrine Command (TRADOC).

Further examples of continuing total Laboratory support to Program Managers is illustrated by the support provided to Army Source Selection Evaluation Boards (SSEB) and to AVSCOM requested technical risk assessments. SSEB activity included: T-700 Growth Engine – 4 engineers; ASE AH-1 Plume Suppressor – 2 engineers; AAH SSEB – 19 engineers; and UTTAS SSEB – 21 engineers for a total of approximately 950 man-weeks of effort. Technical Risk Assessment activity included: AQUILA RPV Risk Assessment; AH-1Q Improved Main Rotor Blade Risk Assessment; and Technical Risk Assessment, OH-58A Main Rotor Mast. Other special assistance included acoustic signature evaluations of all four AAH and UTTAS candidates, utilizing a unique far field in-flight measurement technique developed by the AMRDL Ames Directorate.

A significant action by AMRDL resulted in a cost savings of approximately $300,000 for an antenna modification on the RU-21H Gardrail aircraft. The antennas on this system (eighteen) were failing after 500–1000 flight hours. AMRDL's Eustis Directorate, using the expertise developed on composite materials under the technology base programs, was able in six weeks to develop, test, and install on an aircraft an inexpensive field repair for the antennas.

The Laboratory management was delegated the authority to issue Career Referral Lists for the E&S Career Field, GS-13 and non-supervisory GS-14. This has reduced the processing time for such action from 8 months to 2 months.

The Plans, Programs, and Budget Division of Hq AMRDL has developed a series of Laboratory Management Indicators to be used as an aid in the administration of Laboratory programs. The indicator objectives are three-fold providing the Command Group with:

- Statistical facts
- Graphic trends and comparisons
- Narrative analysis

This procedure, with minor modifications, was used in providing the quarterly Command Review and Analysis presentation to the CG, AVSCOM. The R&A format was recently tailored to meet the requirements of the Commander's Total Management System and covers the general areas of:

- Key Drivers
- Key Workload Indicators
- Thrust Items

In another area of management, the vigorous liaison program between AMRDL and the user of Army aircraft has been maintained. Frequent contacts have been held with the TRADOC and the US Army Forces Command (FORSCOM). These actions have been expanded into two separate actions as follows:

DARCOM Field Engineer Program – This program was established in FY75 in response to a letter by General Vaughan, DARCOM, and consists of individual engineers visiting a unit for a period of 30 days. AMRDL participated in FY76 by sending one civilian engineer with the 101st Division to Operation REFORGER in Germany.

AMRDL/TRADOC Liaison Program – This is an ongoing program established in 1974. During FY76, 13 on-site visits with TRADOC activities were made by AMRDL personnel. At least two trips to each TRADOC School/Center and numerous briefings with TRADOC Headquarters were conducted during the fiscal year.

NOTEWORTHY TECHNICAL ITEMS

To the R&D scientist all technical achievements are noteworthy. However, for this report, a few have been selected as noteworthy and summarized here with more detail provided in the technical achievements section. The most vital function of any military R&D organization is the application of these noteworthy technical achievements, or any other achievements for that matter, to both military and commercial hardware. This transfer of technology is a major ongoing AMRDL effort which is discussed following the technical items.

The Army/NASA XV-15 Tilt Rotor Aircraft Program has made significant progress during FY76 and 7T. The program has advanced from design into fabrication and assembly, with the final assembly of the first aircraft virtually completed. Component and system testing is well underway. Supporting efforts included a piloted simulation to explore boundary conditions on the Ames Flight Simulator for Advanced Aircraft and a full scale rotor test in the Ames 40- by 80-Foot Wind Tunnel.

The Rotor System Research Aircraft (RSRA) is another joint Army/NASA program which will provide a first-time flight research capability for evaluation of new advanced rotor concepts, verification of supporting research technologies, and evaluation and comparison of product improvement rotors. The first of two aircraft has been completed with first flight anticipated in early October 1976.

The Advancing Blade Concept (ABC) aircraft incorporates a coaxial, counterrotating, hingeless rotor system which offers several advantages over conventional rotor systems. The flight test program has successfully demonstrated the concept in the helicopter configuration. The original program also included demonstration of the concept in a compound configuration. R&D funding limitations have delayed and possibly eliminated the flight testing of the compound version.

Developmental flight testing is a "must" tool for any new airmobile concept. However, it is a costly effort usually requiring iterative development steps and considerable flight testing. To reduce both cost and developmental time a Second Generation Comprehensive Helicopter Analysis System is being developed to permit analysis of rotorcraft characteristics such as performance, dynamics, handling qualities, rotor loads, and acoustics in lieu of testing. A joint Government/Industry Working Group has prepared a draft specification detailing the requirements for the analysis to meet both Government and industry needs. This specification will be used as the basis for multiple preliminary design studies for total systems. Following these studies, the specification will be updated for procurement of the system.

A recently initiated effort for the design and fabrication of an Advanced Structures Technology Demonstrator (ASTD) has been expanded from a two phase into a four phase program to include NASA participation. The program, which is based on extensive Laboratory component development experience, will demonstrate the technology improvements achievable through the applications of advanced composite materials and structural design concepts of both primary and secondary rotary wing structures. Specific technology objectives include:

- Reduced structural weight
- Reduced life cycle costs
- Improved ballistic damage tolerance
- Fail-safe structure
- Reduced radar reflectivity

For AMRDL, the transfer of technology must be directed initially to Army operational airmobile systems or emerging systems such as the UTTAS and the AAH helicopters. Equally important is the transfusion of the technology into other military services, governmental agencies, and commercial application. The paths between research concept and ultimate exploitation are usually very diverse. Often the research does not follow directly from initial concept, research, development, and application in a logical sequence as the 6.1, 6.2, 6.3, 6.4 pattern would seem to dictate. Often application occurs in ways that skip whole segments of the classical developmental pattern. For example, the optimum takeoff concept of heavily loaded helicopters, developed by the Ames Directorate, went from an application of modern control theory and a research flight verification program directly into the flight training of Army aviators.

Besides application of hardware and techniques, the transfer of technology occurs in a direct, personal manner through the consultation provided by individuals in AMRDL. In response to the needs and requests of the PMs, field agencies, and the helicopter industry, a wide ranging scope of problems are undertaken, analyses and computations made, and reasoned judgments given. Service on SSEBs, special panels to evaluate critical programs such as the AQUILA RPV, the advanced blade for the AH-1Q, and the mast bumping problem are typical of such efforts. Technical discussions with industry engineers on the state of the technology base such as the stability of the new hingeless tail rotors, nonlinear effects in rotating systems, and Reynolds number effects on new airfoils are an integral and vital function of AMRDL. The unique knowledge existing within AMRDL is passed directly to the industry that provides the Army with its helicopters.

PROGRAM STRUCTURE

The interest of the Army in utilizing the air space has added another dimension to the battlefield for the land combat functions of mobility, intelligence, firepower, combat service support, and command, control and communications. The current operational airmobile systems, developing systems, and R&D planning concepts are shown in figure 2.

LAND COMBAT FUNCTION	MISSION	OPERATIONAL SYSTEMS	DEVELOPING SYSTEMS					R&D PLANNING CONCEPTS						
			AAH	UTTAS	ASH	RPV	CH-47D*	HLH	OV-X	SUR/VTOL	AAWS	LAH	LUH	NMAS
MOBILITY	UTILITY	UH-1		■									▨	
	MEDIUM LIFT	CH-47					■							
	CARGO TRANSPORT	CH-54						▨						
INTELLIGENCE	RSTA/D	LOH			■					▨				
		OV-1D				■			▨					
FIREPOWER	TACTICAL MOBILITY	UH-1	■									▨		
	DESTROY	AH-1	■								▨			
COMBAT SERVICE SUPPORT	UTILITY	UH-1		■									▨	
	MEDIUM LIFT	CH-47					■							
	CARGO TRANSPORT	CH-54												
COMMAND, CONTROL & COMMUNICATION	AVIATION SUPPORT	LOH											▨	▨
		UH-1		■									▨	

*MAJOR MODERNIZATION PROGRAM

Figure 2. Land combat function mission systems.

The Army's aviation needs, represented by the developing airmobile systems and R&D planning concepts, have been analyzed to define technology voids. The R&D program structure must reflect, not only the response to the currently projected capability requirements, but also, the need for a technological base that will fill these voids and will stimulate innovative and imaginative airmobile missions functions, and concepts.

The R&D program of this Laboratory provides the technological base required for fielding these systems with significant improvements over current aircraft in survivability, reliability, maintainability, durability, and operational performance and effectiveness. At the same time the program responds to AVSCOM objectives, DARCOM management-by-objective goals and major thrusts, and DA science and technology objectives and priorities; all within R&D funding limitations.

To maintain and expand the technological base required in the development of advanced airmobile systems, the Laboratory formulates a coordinated program of research, exploratory development, and advanced development in the basic sciences, basic and supporting technologies, and advanced subsystems and technology demonstration. A life-cycle representation of this program structure relating to AMRDL's technologies and disciplines is shown in figure 3.

The Laboratory has prepared the fifth (FY77) edition of the Army Aviation Research, Development, Test, and Engineering (RDT&E) Plan. The Plan is AVSCOM's response to the requirement for a Consolidated R&D Plan and addresses the near- and long-term RDT&E activities that are required for achieving the Army objectives and material needs for which AVSCOM is responsible. This plan presents a time-phased analysis and presentation of the scientific and technological programs that are required for the development of advanced airmobile systems. It is the purpose of this document to set forth plans and objectives for Army aviation research and development activities for the FY77-96 period, with particular emphasis on the period from the present to FY81. It presents, quantitatively, the relationship between the current technological base and future requirements, while taking into account the potential impact of advances in fundamental technologies.

The Laboratory's actual R&D program for FY76 was consistent with the goals and objectives defined in the Army Aviation RDT&E Plan and was oriented, to the maximum extent possible, in the directions of DARCOM goals, R&D thrusts and objectives for FY76, and the Army-User Goals established by DCSOPS. The DARCOM Management-by-Objectives (MBO) goals, major R&D thrusts and AMRDL technical project structure are presented in figure 4. Where necessary, R&D activity has been redirected, terminated, or shifted to meet changing critical areas of need; for example, continuing support of the RPV and terrain flying programs have required considerable Laboratory effort.

The DARCOM major thrusts define express, not exclusive, interests, and so neither the RDT&E Plan nor the Laboratory's program was limited solely to the major thrusts. While most of the Laboratory's efforts have a direct relationship to the major thrusts, the major emphasis is the reduction of life-cycle costs. Thus, such areas are emphasized as: reduced vibratory loads for longer life of dynamic components; improved survivability; increased reliability; reduced vulnerability; use of composites for rotors and fuselage; and new rotor concepts for improved performance and, hence, increased productivity, agility, and survivability. Specific emphasis has been placed on research to improve aircraft night operation, particularly during terrain flying. There are two aircraft roles, scout and attack, which will require terrain flying techniques to survive, but all systems will require this capability when operating in the forward portion of the battle area.

The Requirements Directorate of DCSOPS has provided guidance for the DA Technology Base in the form of prioritized goals (noted above) which represent the operational requirements of the future. This listing was followed by the Laboratory for the prioritizing of the Laboratory's R&D programs at the technology (discipline) level. Program selection at the subdiscipline level as constrained by AMRDL's Command Schedule R&D funds is accomplished by the Laboratory's Project Selection Process identified as OPR (Objectives-Priority-Rationale). (This subject is discussed further in the Planning section of this report.)

While the RDT&E Plan establishes the basis for programming, it is not in itself a program. With the application of funds, programming can be accomplished. The distribution of AMRDL FY76/7T direct funds by program category is shown in figure 5. This distribution applies only to AMRDL and should not be construed as the total distribution of R&D funds for Army aviation. Figure 5 does not include 6.4 activities which are primarily the responsibility of the Directorate for Research, Development and Engineering, AVSCOM. This Laboratory does not have any 6.7 category programs (Operational Systems).

The small amount ($647,000 or 1%) spent on management and support (6.5 program category) consists of expenditures for operation of AMRDL at Ames Research Center ($571,000), operation of a West Coast Technical Industrial Liaison Office ($41,000) at Pasadena, CA, and special purpose equipment and minor construction ($35,000) at the Eustis Directorate. However, Headquarters, AMRDL, located at Ames Research Center, is not charged for the support services provided by NASA. This is another example of improving the effectiveness of resource utilization on a national basis as stated in a previous paragraph.

AMRDL's program structure aligned with a matrix of 6.1, 6.2, and 6.3 program categories and Laboratory developmental functional areas is presented in Appendix A. The FY76 and FY7T AMRDL

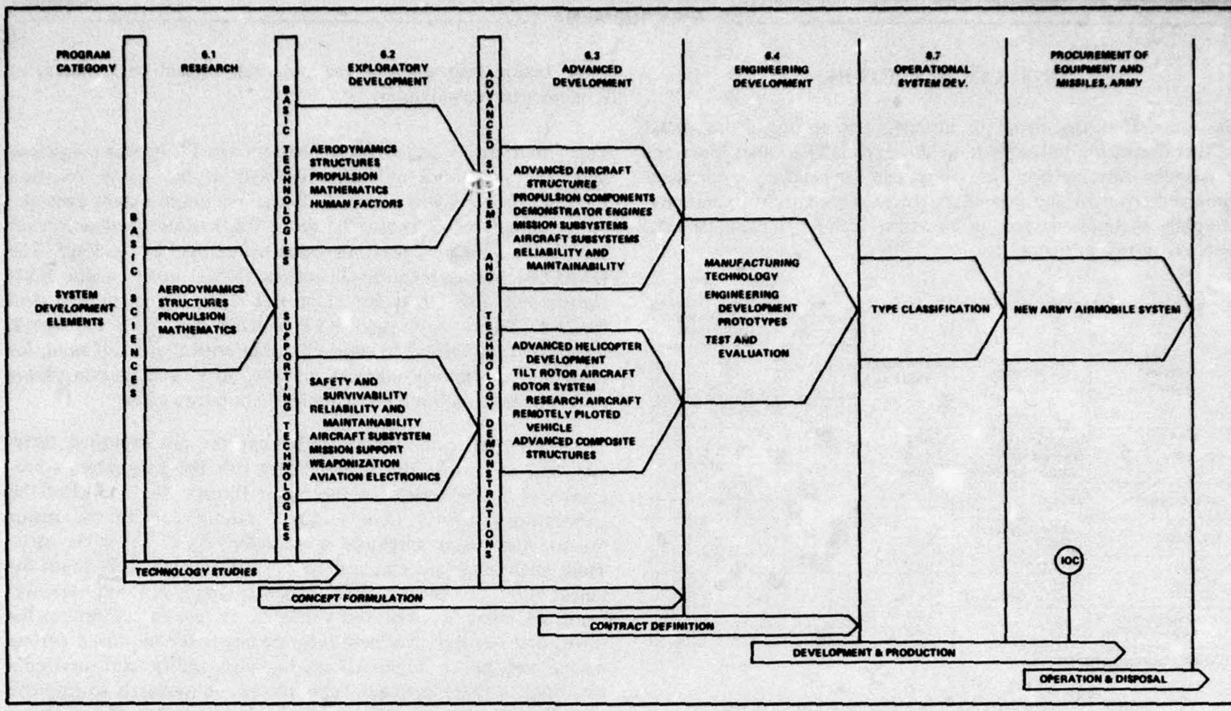

Figure 3. Relationship of technologies for new airmobile systems.

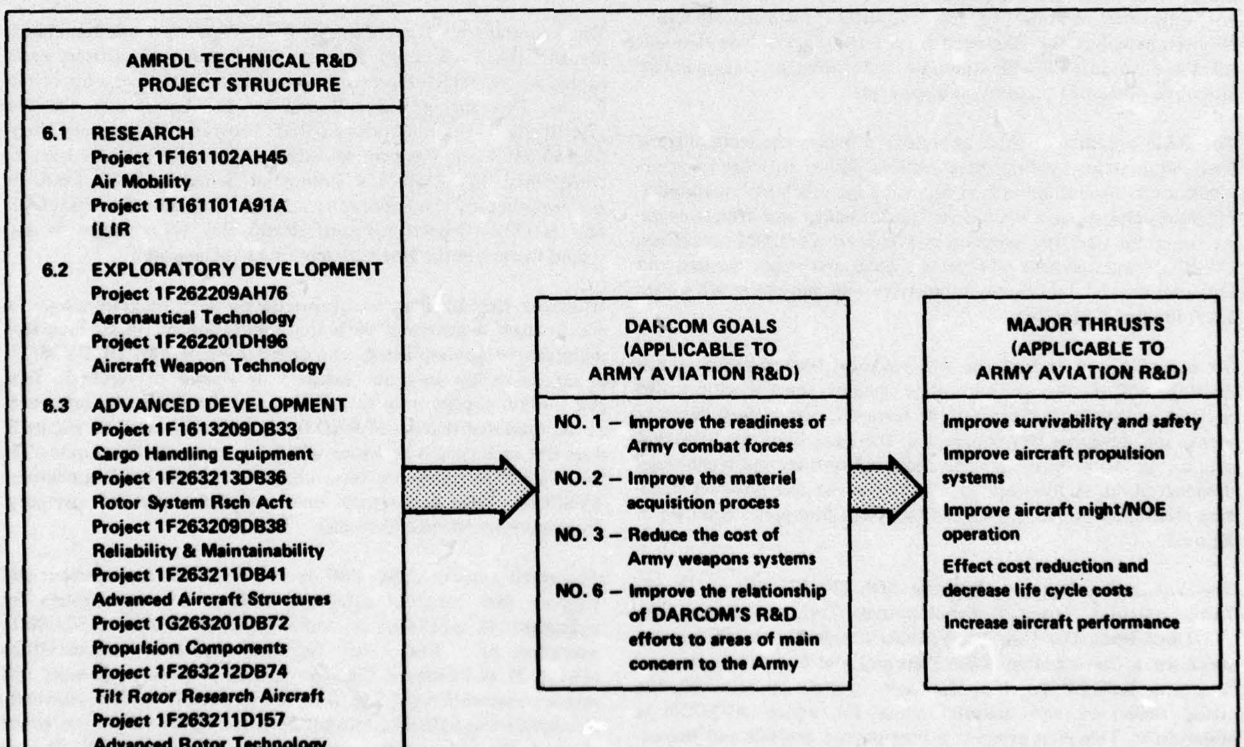

Figure 4. AMRDL technical projects aligned with DARCOM R&D goals and major thrusts.

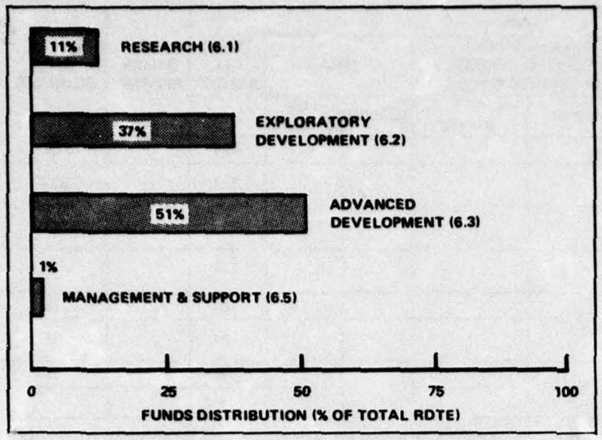

Figure 5. AMRDL direct funds distribution by program category (FY76/7T).

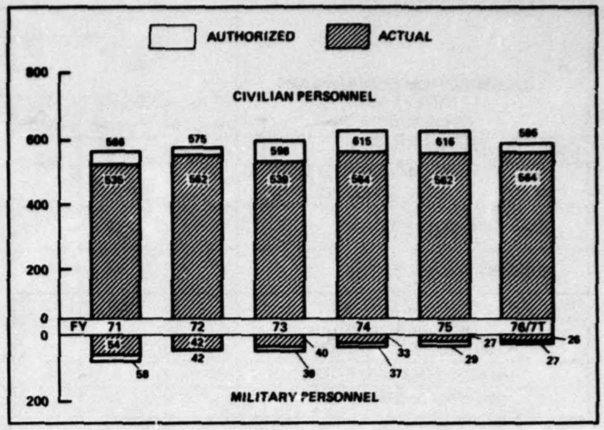

Figure 6. Personnel distribution – FY71-76/7T.

R&D funds are also shown at the tech area/task level with the amount and ratio (percent) of each program category funds devoted to a particular technology.

PERSONNEL AND MANPOWER

The Laboratory has continued to emphasize the recruitment of highly qualified engineers/scientists and administrative personnel against vacant position requirements. In addition, Laboratory management continuously reviews its position structure and manpower requirements to assure the efficient utilization of personnel resources. However, the termination of Project REFLEX and the resultant imposition of a hiring ceiling on AMRDL has reduced the flexibility of the Director in the management of his resources.

As shown in figure 6, the Laboratory's total authorized civilian and military strength has remained relatively constant since the inception of the Laboratory in 1970. During this same time frame, steady progress has been made toward bringing the Laboratory up to full strength. The judicious use of REFLEX authority; the emphasis placed on sound position management; and the support received from NASA Research Centers under the terms of the Army-NASA Support Agreement have been key factors in the Laboratory's personnel and manpower management program. Figure 7 shows the distribution of technical and administrative personnel and also provides a profile of the skills level of technical personnel.

Project REFLEX – Since the AMRDL was established in 1970, until formal notification was received from HQ AVSCOM in March 1976, the Laboratory had operated under the concept of Project REFLEX. Under REFLEX, manpower requirements were correlated to program dollars and in-house/contract workload determinations, as opposed to less appropriate manpower control techniques such as manpower surveys. Despite the fact that Project REFLEX has been terminated and a hiring ceiling imposed on AMRDL, the Laboratory continues to rely on the basic principles of REFLEX as its primary manpower management tool. In addition, the Laboratory has found total grade points to be a valid indicator of personnel costs as opposed to the average grade which does not correlate with costs. Although the Laboratory has not been placed under an arbitrary average grade control, AMRDL's average grade does impact on the average grade of AVSCOM and DARCOM.

Military Manpower Resources – The Laboratory continues to experience the erosion of its military space authorizations with the loss of two more slots in FY76. Since the Laboratory was established, the military authorizations have decreased by 53%, from 58 to 27 spaces. A continuation of this trend will have a detrimental effect on the military/civilian engineering interface that is required for both the development of a strong technology base and the development of Army airmobile systems. This military/civilian interface is essential to the identification and development of systems to meet the needs of the user community and is instrumental to the effectiveness of the Laboratory's liaison efforts with TRADOC and FORSCOM.

Civilian Manpower Resources – The current authorized civilian strength for AMRDL is 586 full-time permanent positions. Despite intensive and continuous efforts, the Laboratory continues to experience difficulty in reaching full strength. Two of the primary contributing factors to this problem is the shortage of qualified personnel in applicable engineering disciplines and the salaries and fringe benefits offered by the private sector. AMRDL has been partially successful in offsetting these obstacles by underslotting positions with target levels for advancement in order to attract younger personnel with high potential. However, average grade policies or other arbitrary personnel and manpower controls are detrimental to this management practice and does not serve as an incentive for continued federal employment.

Complimenting the policy of selectivity in hiring only high potential engineers and scientists, the Laboratory continues to explore all potential sources of highly qualified personnel through aggressive and successful Equal Employment Opportunity Programs. Such special emphasis programs as those for individuals of Hispanic Heritage and for women, as well as the program designed for upward mobility of career employees who demonstrate potential are consistently promoted.

Also in the area of civilian personnel programs, the Alcohol and Drug Abuse Program received strong emphasis during FY76. Finally, a relatively new program, the Federal Program assuring equal employment opportunity for handicapped individuals, received initial implementation at AMRDL.

ORGANIZATIONAL CONFIGURATION AND MANAGEMENT IMPROVEMENTS

The U.S. Army Air Mobility R&D Laboratory was established as an integrated organization with a Headquarters and four operating Directorates as shown in figure 1 (opposite page 1). AMRDL is the laboratory capability of the U.S. Army Aviation Systems Command and is the Army's principal aeronautical research and development field activity.

A. DISTRIBUTION OF MANYEARS OF EFFORT AS OF 30 SEPT 76	ARMY								ALL OTHER APPROP	TOTAL ALL SOURCES
	RDTE			PROCUREMENT SUPPORTED DIRECTLY OR INDIRECTLY BY		OMA		TOTAL ALL APPROP		
	HQ. DARCOM	OTHER DARCOM	NON-DARCOM	DARCOM	NON-DARCOM	DARCOM	NON-DARCOM			
CIVILIAN PERSONNEL TOTAL		564						564		564
*SEE B BELOW — TECHNICAL TOTAL (PROF & TECHNICIAN)		331						331		331
ADMINISTRATIVE TOTAL		233						233		233
SUPPORT & G & A TOTAL		–						–		–
MILITARY PERSONNEL TOTAL		26						26		26
TECHNICAL TOTAL (PROF & TECHNICIAN)		21						21		21
ADMINISTRATIVE TOTAL		5						5		5
SUPPORT & G & A TOTAL		–						–		–

B. PROFILE OF *TECHNICAL PERSONNEL* SKILLS LEVEL	DOCTORS					MASTERS					BACHELORS					OTHER					TOTAL #
	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	
CIVILIAN	28	37	13.0	6	+4	66	36	12.7	10	-4	150	41	12.7	13	-1	87	43	9.1	17	+19	331
OFCRS(01-010)	2	36	4.0	–	+100	7	39	4.9	–	-22	5	39	3.8	–	-17	1	37	3	–	+100	15
MILITARY WO(W1-W4)	0	–	–	–	–	0	–	–	–	–	0	–	–	–	–	1	40	3	–	-50	1
EM(E1-E9)	0	–	–	–	–	0	–	–	–	–	1	27	E4	–	+100	4	30	E5	–	+33	5

C. WORKFORCE STRENGTH IN PEOPLE ON BOARD AS OF 30 SEP 76	
CIVILIAN	564
MILITARY	26
TOTAL	590

**PERCENT CHANGE (+/-) SINCE FY 75 IN NUMBER (#) ONLY.

Figure 7. Distribution of man-years of effort for AMRDL as of 30 Sep 76.

The concept of operations established for the Laboratory emphasizes the following:

- Ensure that a balanced total AMRDL R&D program is established and achieved;
- Increase the effectiveness of support to product developers to ensure improvements in their airmobile systems;
- Provide means for assuring an orderly continuity of efforts from research through exploratory development to demonstration of technology and transfer of knowledge to developers for application.

A management team, composed of the senior managers of the Laboratory, assists the Director in assuring that effective utilization is made of resources for successful mission accomplishment.

The Laboratory management directs its activities to achieve balance between the development and demonstration of technology and the requirement for support of specific airmobile systems concepts. All four of the subordinate Directorates are totally involved in all aspects of the Laboratory mission; however, specific emphasis is given to particular disciplines in each of the Directorates. For example, in the three Directorates collocated with NASA, the largest part of the effort is directed toward research and exploratory development to increase knowledge in the physical and behavioral sciences. Such efforts may, in some cases, be orientated toward recognized operational objectives but may not relate directly to a specific system. Conversely, the primary mission of the Eustis Directorate is in the areas of technological application, military operations technology, and technical support to systems developers. The Eustis Directorate plays a major role in the transfer of technology to industry and the Army users.

At each of the three NASA-collocated Directorates, there is an Army Aeronautical Research Group directly under the operational control of the Director of that Directorate. There is also a Joint Aeronautical Research Group that consists of Army employees working side by side with NASA employees under operational control of NASA supervisors. The efforts of this group are on a broader scope, pursuing mutual interests of both agencies. A Technical Support Group, which consists of a limited number of support professionals and technicians under NASA operational management, provides support to the Army.

The support functions for the three Directorates collocated with NASA Research Centers are largely provided through negotiations with NASA resulting in a minimum allotment of Army resources. Technical support is negotiated by the Director and includes NASA shop capabilities, graphics and reproduction, library and document facilities, computing facilities and specialist's laboratory and calibration functions. Similarly, administrative support is provided in terms of procurement, fiscal and accounting, travel, and other associated services. Monetary resources are supplied to NASA on a reimbursable authority. Program authority is exercised over Army resources by the Laboratory through allocation of program resources against a stipulated plan. Effectiveness and conformance are judged by audit procedures. A limited in-house administrative capability is provided in each of these Directorates to monitor the administrative support services, prepare programs, and perform necessary regulatory functions.

A comparable support function by Army personnel exists at the Eustis Directorate. A Contracting Division, a Legal Division, a Technical Support Division, and an Administrative Support Division report directly to the Director, Eustis Directorate. The Contracting and Legal Divisions are total Laboratory resources and, at the discretion of the Laboratory Director, service other

Directorates as required; such instances would occur, for example, when an Army awarded contract is dictated rather than a NASA contract.

The Laboratory Director controls, through the Headquarter's Policy, Plans, and Programs Office, the use of all money resources against approved documents. The authority to contract, delegated to the Director, AMRDL, is redelegated to the Director, Eustis Directorate, who exercises the authority against approved program through the contracting division located at Eustis. Funds supplied to NASA for contract are controlled by the Directors of the Directorates against a program approved by the Director, AMRDL.

Throughout the Laboratory, the concept of vertical alignment is applied to reduce administrative burden and to provide maximum flexibility in the use of technical manpower against continually varying technical emphasis. Vertical alignment provides the ability to readily shift the staff of the Laboratory without detailing, including the mix of specialties and grade levels, in response to the current need, rather than in conformance to an arbitrary organization. Vertical alignment contributes greatly to increased productivity, reduces requirements for services from supporting organizations, and has demonstrated its value in increased responsiveness to customer needs.

Integration of Army aviation R&D capability into AMRDL as a single operating unit has resulted in more effective resource utilization and program responsiveness than was possible with the previous separate research and development organizations. It has provided a management structure with maximum flexibility in the utilization of manpower resources and has established a single point of contact for Laboratory assistance to system and product developers. Further integration of Army aviation scientific and engineering capability is warranted and should be pursued. The Laboratory is participating in a Memorandum of Understanding (MOU) arranged between the Army (AMRDL) and the French Office National d'Etudes de Recherches Aerospatiales. Under this management agreement, specific areas of mutual research interest are spelled out, and there is an extensive interchange of research information. Research engineers from France work within the Laboratory and AMRDL engineers work in France on rotational assignments. Extremely complex problems, such as dynamic stall of rotor blades, have benefited directly from such a close interchange.

PLANNING

The Army Aviation RDT&E Plan provides the basis for the Laboratory's program planning. The RDT&E Plan addresses the plans and objectives for Army Aviation R&D activities for the next 20-year period, with particular emphasis on the near-term 5-year period. It relates, in a quantitative manner, the current technological base to the projected future requirements.

The specific emphases for revision in the FY77 update of the plan were (October 1976 publication date):

- Align programs with DA Science and Technology Objectives Guide (STOG-77) (CONFIDENTIAL).
- Reappraise all near- and far-term objectives with respect to STOG-77, Catalog of Approval Requirements Document (CARDS), July 1973 (SECRET), and DARCOM MBO Goals.
- Update status of all Army airmobile systems discussed in the Plan.
- Realign Army airmobile systems based on land combat function missions.
- Realign Army airmobile systems as operational systems, developing systems, and R&D planning concepts.
- Introduce Laboratory OPR project selection process in technology program planning.
- Continue publication of an unclassified edition of the Plan for use by the aviation community.

The Plan seeks to explore all viable options for future systems with the goal of providing a range of choices and a means for selecting candidates for development when required. As the operational dates become more distant, a larger number of options can be pursued and at a more fundamental level of research. The Plan is intended to be a management tool to provide visibility of acknowledged requirements and interdependence of necessary technological achievements. While the Plan establishes the basis for programming, it is not in itself a program. It is not constrained by available resources in its stated objectives and corresponding R&D to implement them.

The Plan focuses RDT&E activities to guide the Army's funds into areas of greatest effectiveness. Thus, R&D effort is directed toward ensuring that the most advanced technology is available for use in near-term projects. For new systems further downstream, the effort is directed toward minimizing technical barriers, optimizing key performance factors, and narrowing the options to the most viable. Plans for development of new systems, technological improvement objectives, plans to reach these objectives, and past trends are described in the document.

Desired capabilities and Initial Operational Capability (IOC) dates for most of the projected airmobile systems are based on currently available documentation. For each of the Army's airmobile systems, the mission, key factors, and salient characteristics that determine its performance requirements are discussed in detail in the Plan. These considerations are summarized in Table I. The missions and the key performance factors are based on current projections of the Army's aviation needs. Conceptual and design studies are conducted to assess advances in each area of technology with respect to their impact on aircraft systems. Such studies are used to identify those areas that appear to hold the highest potential. Gaps in scientific disciplines or supporting technologies are identified. Such studies constitute a major and continuing function of the Laboratory's Advanced Systems Research Office (ASRO).

During the preparation of the RDT&E Plan, consideration was given to the relevant R&D programs of other Army organizations. In particular, activities are coordinated in the areas of human factors, avionics, ground handling, and weapons where performance requirements necessitate the integration of these factors into the total airmobile system, but where mission responsibility for appropriate R&D is in another commodity command or corporate laboratory. Moreover, the Laboratory recognizes and maintains an interchange with those organizations that have been designated as "Lead Laboratories" and whose charters encompass technologies important to Army aviation. For example, this Laboratory has activities and interests that relate directly to the work in fluidics at Harry Diamond Laboratory, to the materials research at Army Materials and Mechanics Research Center, and to the efforts of U.S. Army Electronics Command's Night Vision Laboratory in night operations. Although the AMRDL does not have a "charter," its mission does, in effect, establish the Laboratory as the "Lead Laboratory" in Army airmobile systems.

The RDT&E Plan clearly indicates that VTOL aircraft technology can expect significant advances over the 20-year time frame, which, in turn, can affect the aircraft systems designed in the 1977-1996 time period. The precise magnitude of technological

TABLE I. ARMY AIRMOBILE SYSTEMS, MISSIONS, AND KEY PERFORMANCE FACTORS

SYSTEM	MISSION	KEY PERFORMANCE FACTOR
AAH	• Provide Aerial Fire Support • Tactical Mobility and Support	• Acquire/Destroy Targets • Survivability
UTTAS	• Squad Carrier • Combat Service Support	• Low Life Cycle Cost • R&M Improvements
ASH	• RSTA/D • Direct Aerial Fire Support	• All Weather Day/Night Capability • Agility
RPV	• Unmanned RSTA/D	• Low Acquisition Cost
CH-47D	• Medium Lift Transport	• Payload • Reliability
HLH	• Transport of Cargo • Retrieval of Equipment	• Capacity • Precision Hover
OV-X	• Intelligence • Electronic Warfare	• Endurance • Payload
SUR/VTOL	• Intelligence • Electronic Warfare	• Forward Area Operation • Penetration Capability
AAWS	• Area and Point Target Suppression • Extended Area Reconnaissance	• Acquire/Destroy Targets • Survivability
LAH	• Armed Reconnaissance • Area and Point Target Suppression	• Survivability • Compatible with ASH
LUH	• Troop Lift • Utility Transport	• All Weather Capability • Compatible with ASH
MMAS	• Observation • Visual Reconnaissance • Command and Control	• Forward Area Operation • Operation/Maintenance Simplicity

improvement that can be achieved is governed by other than purely technical considerations, of which the most important are the necessary budgetary and schedule constraints.

The Plan becomes the program when the required resources in terms of funds, facilities, and personnel are provided for its implementation. Even if unlimited resources were available, it is not likely that all the efforts would be pursued and all of the goals achieved. Therefore, it would be unrealistic to make an estimate of resource requirements that is based on the development of all the concepts for each of the projected systems. Moreover, the available options and alternatives to perform a given task diminish rapidly with time, so estimates of resource requirements are valid only on a relatively short-term basis. Even more to the point, however, is the fact that there are never enough resources to undertake all of the research projects that optimum planning would indicate; there are generally many more feasible technical alternatives available to solve a particular problem than can be economically supported. Under conditions of limited resources, imposed economics, and prescribed goals, a logical resource allocation methodology is the key to orderly progress. The Laboratory's Project Selection Process was developed to provide AMRDL management a program selection means based on R&D objectives, priorities and supporting rationale. This process is described in detail in the RDT&E Plan with application to each of AMRDL's technology disciplines.

The Advanced Systems Research Office of AMRDL, under the Aircraft Systems Synthesis Project, directs the development of the Army Aviation RDT&E Plan and is responsible for the development and application of the project selection process (OPR). The OPR procedure is the means to provide Laboratory management with the guidance necessary to properly tie the planning and programming to budgeting.

The development of the Laboratory Project Selection Process requires:

- Clear definition of fundamental laboratory technical objectives,
- Priority of these objectives,
- Rationale supporting the technical thrust (effort).

The budget process is a recurring one in which the Laboratory and its Headquarters AVSCOM and DARCOM are involved. The cycle begins with a five-year funding guidance document, the Command Schedule. Upon receipt of the Command Schedule, the Laboratory prepares proposed programs and plans for a three-year period (AMC Form 1534 – RDTE Program Data Sheet and DD Form 1634 – Research and Development Planning Summary) in response to the guidance document. These programs and plans are then submitted to DARCOM through AVSCOM for review. Guidance (AMC Form 1006 – Program Directive/Program Change Request) from DARCOM is issued which constitutes expected funding for the next fiscal year. Proposed programs (AMC Form 1006A – Program Directive/Program Change Request) are then prepared by the Laboratory detailing specific efforts to be undertaken in view of this guidance. The cycle repeats each fiscal year with the issuance of a new Command Schedule.

To assist in the development of the above AVSCOM/DARCOM program documentation, the Laboratory Directorates provide detailed program planning at the research element work unit level. The procedure, identified as AMRDL Annual Narrative Program (ANP) describes planned activities for a three-year period and provides budgetary information and milestones for a five-year period.

OUTSIDE/INSIDE EXPENDITURES

The distribution of FY76/7T program funds received by AMRDL as presented in Table II is categorized under three basic headings: Industry or Academic, other DARCOM Labs, and other Government Agencies, for each of the program categories; i.e., 6.1, 6.2, etc. Within each category, the amount for contract (outside) and the total amount for that category are listed. The ratio (percent) of the outside contract amount to total each program category are obtained by subtracting the three contract expenditures from the total.

The contract monies under industry or academic institutions include contracted efforts purchased through NASA procurement in direct support of the in-house research efforts at the three Directorates collocated with NASA Research Centers. In regard to the outside/inside expenditures, Table II, it is important to note that, of the total expenditures in the 6.1 and 6.2 categories, \$13.7 million or 50.0% was spent in-house. On the other hand, of the total RDT&E money only \$19.7 million or 33.7% was spent in-house.

As R&D efforts progress through exploratory development to advanced development, the hardware required to conduct research increases. This results in an increase both in dollar amount and percentage of contracted work, as reflected in the 6.3 category. The largest portion of these projects is contracted by the Contracting Division at the Eustis Directorate. In most of these cases, the in-house operation costs applicable for contract administration is provided in the estimated cost to administer column, Table II.

The policy of the Laboratory has been to maintain a balance of not less than one dollar in-house to two dollars out-of-house work for its entire area of responsibility. This policy does not result

from guidelines for constraints from higher level, but rather is considered to be a proper ratio in order to maintain both in-house expertise and responsiveness in the industry that supplies the commodities for the Command. As stated in the previous paragraph, the 6.2 category required more in-house effort as compared to the 6.3 category. In FY76/7T, 44% of AMRDL direct funds were distributed into the 6.2 category while in FY75 the ratio was 43%. Justification for contract versus in-house is based upon the most effective use of resources and the best mechanism for accomplishing programs goals. The flexibilities of funding provided by SPEF and management of manning levels under REFLEX remove some of the constraints of outside control in a given case, and permit Laboratory management to make decisions based primarily on the merits of the R&D needs of the Army rather than on artificial constraints.

It is the policy of the Laboratory to utilize the expertise and specialized capabilities of other DARCOM Labs/Installations to conserve resources and prevent duplication of effort in accomplishing the Laboratory mission. During FY76/7T, a total of $1.9 million or 4.1% of this Laboratory's direct program funds were distributed to the DARCOM Labs/Installations shown in Table III. It is the intent of the Laboratory's management that the above policy will continue in the future.

TABLE II. FY76/7T OUTSIDE/INSIDE EXPENDITURES (AS OF 30 SEP 76)

TOTAL LAB EFFORT	INDUSTRY AND ACADEMIC			OTHER DARCOM LABS			OTHER GOVERNMENT AGENCIES			ESTIMATED COST TO ADMINISTER*	
	Contract	Total**	Ratio	Contract	Total**	Ratio	Contract	Total**	Ratio		
RDTE FUNDS	$K	$K	%	$K	$K	%	$K	$K	%	$K	%
6.1 Research	1927	6235	30.9	0	6235	0	0	6235	0	147	2.4
6.2 Exploratory Development	10310	21039	49.0	1182	21039	5.6	202	21039	1.0	1976	9.4
6.3 Advanced Development											
6.3a	15456	19456	79.4	62	19456	0.3	168	19456	0.9	1012	5.2
6.3b	8655	10051	86.1	100	10051	9.9	33	10051	0	531	5.3
6.4 Engineering Development	736	1221	60.3	25	1221	2.0	0	1221	0	160	13.1
6.5 Mgt & Support	45	647	7.0	4	647	0.6	0	647	0	0	0
6.7 Oper Systems	0	0	0	0	0	0	0	0	0	0	0
RDTE TOTAL	[illegible]	[illegible]	[illegible]	1373	[illegible]	2.3	403	[illegible]	0.7	[illegible]	[illegible]
PROCUREMENT FUNDS											
DARCOM	742	818	90.7	0	818	0	0	818	0	70	8.6
Non-DARCOM (Other Army)	0	0	0	0	0	0	0	0	0	0	0
Non-Army	0	0	0	0	0	0	0	0	0	0	0
PEMA TOTAL	742	818	90.7	0	818	0	0	818	0	70	[illegible]
OMA FUNDS											
DARCOM	96	138	69.6	0	148	0	0	138	0	20	14.5
Non-DARCOM (Other Army)	0	81	0	0	81	0	0	81	0	0	0
Non-Army	0	50	0	0	50	0	0	50	0	0	0
OMA TOTAL	[illegible]	[illegible]	35.7	0	[illegible]	0	0	[illegible]	0	[illegible]	[illegible]
GRAND TOTAL	[illegible]	[illegible]	63.6	1373	[illegible]	2.3	403	[illegible]	0.7	[illegible]	[illegible]

*Total expenditure for each line; i.e., 6.1, 6.2, etc.
**In-house cost for purely administrative duties, both technical and managerial.

TABLE III. DARCOM LABS/INSTALLATIONS USED BY AMRDL

DARCOM LABS/INSTALLATIONS	PURPOSE
ARMY MATERIAL & MECHANICAL RESEARCH CENTER	• Research in Safety and Survivability • Support in Aircraft Structures
BALLISTICS RESEARCH CENTER	• Research in Safety and Survivability
FRANKFORD ARSENAL	• Aircraft Weapons Technology – Fire Control
MOBILITY EQUIPMENT R&D COMMAND	• Mini-RPV Propulsion
PICATINNY ARSENAL	• Aircraft Weapons Technology – Free Flight Rocket
ROCK ISLAND ARSENAL	• Aircraft Weapons Technology – Guns & Mount
WATERVLIET ARSENAL	• Research on Structures

PROGRAM BALANCE

The program structure for the Laboratory in FY76/7T by funding allocations is reflected in Table IV. The total Laboratory funding for the Army Aviation R&D Program, including reimbursable orders amounts to $59.7 million – a small percentage of the Army's total RDT&E budget, and even smaller in comparison with the total resources expended for airmobile systems development and procurement.

The reimbursable program for FY76/7T amounts to $13 million, a portion of this amount was received from the OMA and PEMA funded programs as shown in Table V.

Joint participation agreements have enabled the Army and NASA to enter into mutually beneficial research and development programs which neither one could afford to pursue alone. Notable among such projects are the developments of the Tilt-Rotor Research Aircraft at Ames Research Center and the Rotor Systems Research Aircraft at Langley Research Center. These programs, along with others, have both military and civil applications and thus, improve the effectiveness of resource utilization on a national basis.

The Laboratory's Funding Summary; Command Schedule, Direct Funding Authority, and Obligational Authority, for the period of FY72 through FY76 is presented in figure 8. With careful planning and management, the Laboratory has obligated no less than 96.8% of its available program funds for each of these fiscal years. The 96.8% obligation rate for each fiscal year exceeds the DARCOM goal of 96%. Continued success in this area depends on careful program management. Moreover, any significant amount of deferred or late release of funding could lead to serious obligation problems as reflected in the FY76 obligation rate. The delay associated with late releases of funds could result in inability to explicitly define the work to be done and proposal evaluation lacking in proper depth and, hence, could adversely affect the quality of the ultimate R&D product. The FY7T period was not included in figure 8 as the obligation period for the transition period extends through December 1976.

The concept of single project/program element funding (SPF/SPEF) has gained significant acceptance since its implementation. The advantage of the SPF/SPEF program in providing broad local management flexibility by removing some intra-program element reprogramming restrictions results in a decrease in some individual project visibility at higher levels. As a result,

TABLE IV. FY76/7T FUNDING/INCOME BREAKOUT FROM ALL SOURCES INCLUDING CUSTOMERS (AS OF 30 JUN AND 30 SEP 76)

PROGRAM BREAKOUT	SUBTOTAL FY76	SUBTOTAL FY7T	TOTAL
RDTE FUNDS			
6.1 Research	4900	1335	6235
6.2 Exploratory Development	16569	4470	21039
6.3 Advanced Development	24431	5076	29507
6.3a 15802/3654			
6.3b 8629/1422			
6.4 Engineering Development	1120	101	1221
6.5 Management & Support	522	125	647
6.7 Operational Systems	0	0	0
RDTE TOTAL	47942	11107	[illegible]
PROCUREMENT FUNDS (PEMA)			
DARCOM - Hq	0	0	0
- Other	698	120	818
Non-DARCOM (Other Army)	0	0	0
Non-Army	0	0	0
PEMA TOTAL	698	120	818
OMA FUNDS			
DARCOM - Hq	0	0	0
- Other	138	0	138
Non-DARCOM (Other Army)	66	15	81
Non-Army	0	50	50
OMA TOTAL	204	65	269
GRAND TOTAL	48844	11292	59736

INCOME BREAKOUT	FY76	FY7T	TOTAL
DARCOM SOURCE			
Hq, DARCOM	37167	9570	46737
AVSCOM	10774	1643	12417
Other DARCOM Customer	326	14	340
SUBTOTAL	[illegible]	[illegible]	[illegible]
Non-DARCOM Customer (Other Army)			
Army Security Agency	3	0	3
Army Training and Doctrine Command	63	15	78
SUBTOTAL	66	15	81
NON-ARMY			
NASA	50	0	50
Navy	17	50	67
Marine Corps	44	0	44
SUBTOTAL	111	50	161
GRAND TOTAL	48844	11292	59736

FUNDS IN THOUSANDS OF DOLLARS

TABLE V. REIMBURSABLE PROGRAM

SOURCE	PROGRAM	FUNDS
ARMY		
TRADOC	UTTAS	OMA
TRADOC	TMI Support	OMA
AVSCOM	Project INSPECT	OMA
AVSCOM	T-700 Tech Support	OMA
Ft. Hood	HYSAS	OMA
Army Sec. Agency	Antenna	OMA
AVSCOM	AH-1Q Blade NDT	PEMA
AVSCOM	MM&T	PEMA
NAVY	JTCC	OMA

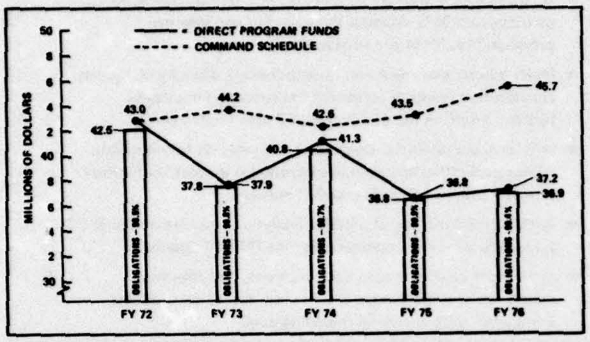

Figure 8. Funding history – FY72-76.

additional reports have been levied upon the Laboratory. It is believed that in order to obtain the optimum benefits from SPF/SPEF, additional reporting must be eliminated or reduced and minimum required information should be generated within the existing budget, accounting and program reports.

TECHNICAL ACHIEVEMENTS

The principal AMRDL R&D goal is to maximize mission capabilities and operational effectiveness of Army airmobile systems while minimizing life-cycle costs. The FY76/7T program for the Laboratory was responsive specifically to DA/DARCOM/AVSCOM identified goals and objectives as they impact air mobility research and development. Table VI identifies some of the Laboratory's accomplishments in FY76/7T that are directly related to these goals and objectives.

The technological improvement objectives of the FY76/7T projects were consistent with the near-term objectives identified in the Army Aviation RDT&E Plan of July 1975.

The following summary of some of the Laboratory's more significant achievements during FY76/7T is divided into:

- Research – 6.1
- Exploratory Development – 6.2
- Advanced Development – 6.3a
- Laboratory Support Actions – 6.3b

The published output of the Laboratory in terms of in-house and contract activity is documented in Appendix B.

AIR MOBILITY-PROGRAM CATEGORY 6.1

RESEARCH IN AERODYNAMICS

A detailed understanding of the aerodynamics of helicopters is particularly difficult to achieve due to the complex time-varying flow field in which a helicopter rotor operates. Helicopter performance, aeroelastic stability, vibration, static and dynamic loads, handling qualities, agility and acoustic signature are all directly related to the nature of the helicopter aerodynamic flow field.

Advances in these fundamental areas can have a far-ranging impact in the exploitation and economics of the helicopter, and thus a wide range of the Laboratory's research effort is dedicated toward aerodynamics.

2-D Airfoil Sections – The major efforts in airfoil section development have traditionally been oriented toward fixed-wing aircraft applications. The unique flow field of the helicopter rotor requires a different set of airfoil characteristics than those desirable for fixed-wing aircraft. Significant progress has been made toward development of a technology for improving airfoil section aerodynamic characteristics for helicopter applications. A systematic approach to developing advanced airfoils which meet the peculiar needs of the helicopter has been undertaken and several advanced sections have been analytically defined. A systematic set of two-dimensional airfoil lift, drag and moment coefficient data for a new family of rotorcraft airfoils is being collected, with section modification as necessary to produce good transonic drag characteristics at moderate Mach numbers.

Rotary-Wing Airfoil Dynamic Stall – During maneuvers at high forward speed conditions, large unsteady airloads are applied to the rotor blade due to dynamic stall of the retreating blade. This phenomenon has been investigated by means of wind-tunnel tests of properly scaled oscillating airfoils. This research has demonstrated the true nature of the boundary layer separation mechanism in causing dynamic stall. It has been shown that airfoil normal force and pitching moment data for airfoils oscillating through stall can be non-dimensionalized to collapse to a single scale curve which is independent of Reynolds number and reduced frequency. These non-dimensional curves may constitute a basis for developing a practical predictive technique for general use. The goal of this research is to supply a satisfactory dynamic stall load prediction method for the helicopter industry. An associated objective is to identify the process by which dynamic stall is triggered, and from this, develop a technique for modifying the dynamic stall. These dynamic stall theoretical-experimental programs rely heavily on the capability to visualize the flow process during dynamic stall. The water tunnel at the Ames Research Center, shown in figure 9, has been very effective in providing detailed flow visualization through the use of electrolysis-generated hydrogen bubbles which are utilized in time-motion analysis of dynamic stall.

Rotor Flow-Field Test Technique – The laser velocimeter has been developed as an especially useful tool for measuring the rotor downwash, the trailing tip vortex and the bound circulation on the blade. Recently, this concept has been made even more useful to rotor studies, by strobing the laser to the rotor rotation and using it to study the blade-vortex interaction problem. However, this technique generates large volumes of data in short periods of testing time and data handling has become a significant problem. New real-time data processing equipment has been added to the laser velocimeter system developed at the Ames Research Center, which has dramatically reduced the man-hours and rotor operating times required for the blade-vortex experiments. This new system uses a PDP-11 computer to process the data and a Textronic graphic display with a hard copy attachment for, essentially, real-time data

TABLE VI. REPRESENTATIVE FY76/7T ACCOMPLISHMENTS

FY76/7T ACCOMPLISHMENTS	MAJOR THRUST	PROJECTED BENEFITS AND IMPACT
FLOW EFFECTS ON ROTORS	• Increases Aircraft Performance	• Laser velocimeter and laser/doppler techniques for measurement of rotor downwash, tip vortex, and boundary circulation provide more accurate performance prediction. The addition of strobing the laser has enhanced study of blade/vortex interaction
AIRFOIL DYNAMIC STALL	• Increase Aircraft Performance	• Reduction of rotor loads and vibration through control of dynamic stall of retreating blade thereby increasing maneuver and high forward speed capability.
CARGO HANDLING	• Improve Aircraft Night/NOE Operation	• Provide terrain flying capability for movement of external cargo in a high threat environment under adverse weather conditions.
HELICOPTER ICING	• Improve Safety and Performance	• Icing requirements established with research efforts identified to provide adverse weather operational capability.
ADVANCED TECHNOLOGY DEMONSTRATOR ENGINE	• Improve Aircraft Propulsion System	• ATDE program initiated to decrease SFC by 20%, increase hp/lb of airflow by 30%, decrease vulnerability and improve producibility, RAM and survivability.
ADVANCED COMPOSITE MAIN ROTOR BLADE	• Improve Survivability & Effect Cost Reduction	• Multi-tubular spar main rotor blade concept utilizing composite construction indicates an overall improvement in damage resistance/fatigue life of a factor of 2 over metal blades.
RPV TECHNOLOGY	• Increase Performanc & Effect Cost Reduction	• RPV concept potential established and solution to immediate problems limiting operational utilization is in work with effort directed toward full scale proof of concept.
ARMS MODEL FOR UTTAS	• Decrease Life Cycle Cost	• ARMS model utilized in a COEA analysis of a comparative R&M evaluation of viable candidates for the UTTAS mission.
FLIGHT SAFETY	• Increase Safety & Survivability	• Conducted cargo restraint, crew restraint, and structural experiments on a full scale CH-47 crash test to provide test correlation with analytical modeling data.

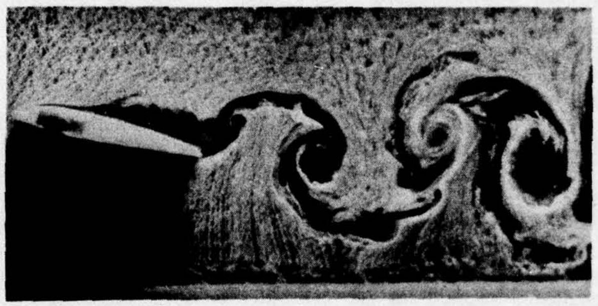

Figure 9. Flow field over an oscillating airfoil in the water tunnel using electrolysis-generated hydrogen bubbles.

acquisition, processing, monitoring and recording. A typical data plot is shown in figure 10. By strobing the laser to the rotor rpm, the tip vortex location and strength have been measured at azimuthal positions from immediately behind the blade to 180° behind the blade where the second blade of a two-bladed rotor interacts with the vortex. Simultaneous near-field sound measurements were also recorded to obtain experimental data for correlation with theoretical calculations.

Aeroelastic Stability Analysis – Dynamic stability of rotors, in general, and hingeless rotors, in particular, need more detailed understanding of basic phenomena. Consideration is being given to stability of the isolated rotor blade, mounted on a fixed hub, and to stability characteristics of the coupled rotor-bodied system. For the isolated rotor blade, analyses includes simplified rigid-blade representations, as well as more elaborate uniform and nonuniform elastic-blade models. The work emphasizes low frequency stability characteristics in hovering flight, where structural coupling phenomena of bending and torsional motions can be

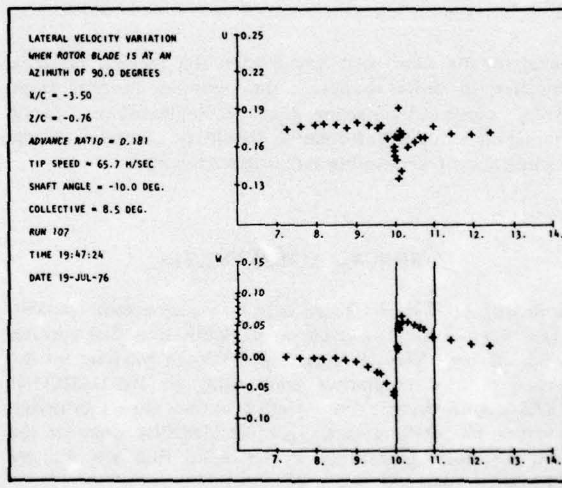

Figure 10. Typical data plot from Textronic graphic terminal for laser flow measurements.

important. This is especially true for advanced bearingless rotor configurations. Some progress has also been made in understanding the effects of forward flight and of unsteady aerodynamics on the blade stability characteristics. Mathematical models are being developed to represent the coupled rotor-body dynamics problem in both hovering and forward-flight conditions. Primary emphasis, at the present time, is on the simpler rigid-blade representation. These analyses, supported by scale-model analysis, are intended to provide a clear understanding of mechanical stability phenomena, such as ground and air resonance stability of hingeless rotor helicopters to assure that such problems are avoided early in the design of new helicopter systems.

Rotor Dynamics Model – The rotor dynamics model (RDM), shown in figure 11 is a major tool for generating experimental data to correlate with theoretical analysis of basic dynamic phenomena. This versatile model may be used for investigations of rotor blade stability, coupled rotor-body stability, and of rotor loads with or without the effects of body dynamics. Recent experiments have included investigations of configuration concepts designed to increase the inherent stability of the isolated rotor blade lead-lag modes. Measured blade damping was in good agreement with theoretical predictions. Experiments presently planned, or in progress, involve measurements of the stability characteristics of the coupled rotor-body system and of isolated torsionally flexible elastic blades, specially designed to verify analytical methods recently developed. The RDM was also used to measure blade loads in forward flight for various hub restraint conditions. Under a U.S.-France MOU, these test data will be used to correlate with an analytical technique that has been developed in France. Analysis of the test data and correlations with the theory, are currently in progress.

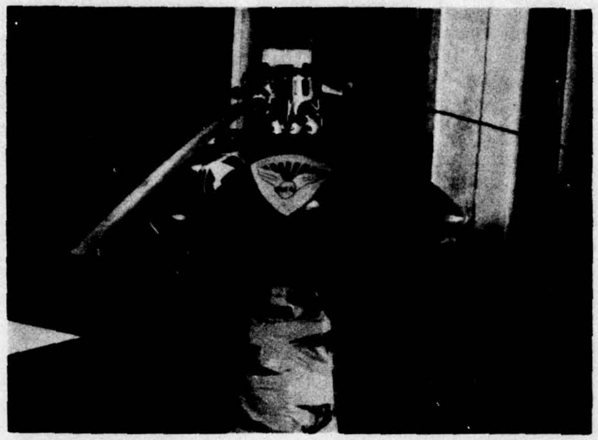

Figure 11. Rotor dynamics model.

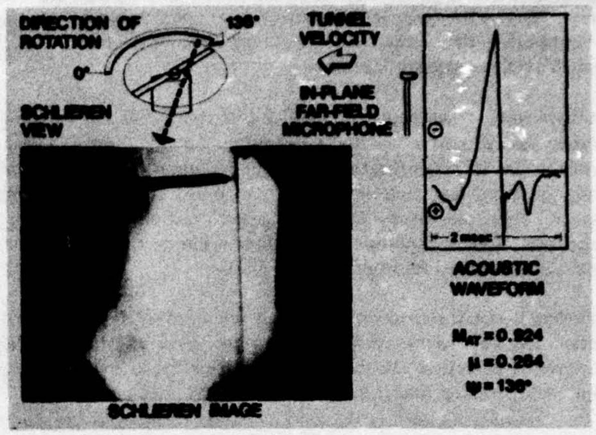

Figure 12. Schlieren image and corresponding waveform.

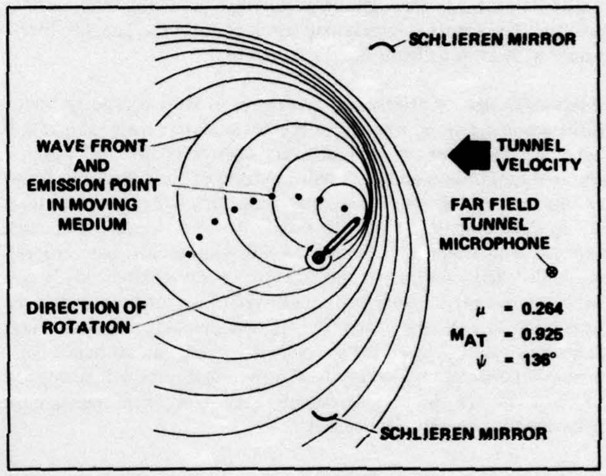

Figure 13. Geometric pattern of high-speed impulsive noise.

High-Speed Helicopter Impulsive Noise – Forward flight impulsive noise data from a 1/7-scale UH-1H rotor were accrued in the acoustically treated Ames 7- by 10-Foot Wind Tunnel and compared with full-scale flight test data for the same helicopter. Good agreement between model and full-scale waveforms and peak pressure amplitudes was found when key performance parameters were matched and the data was acoustically scaled.

The acoustic waveform exhibits changes in character as advancing tip Mach number is increased – from triangular shape at low advancing tip Mach number to sawtooth with a near discontinuous pressure rise at high advancing tip Mach number. This step increase in acoustic pressure correlates with schlieren photographs of a periodic pressure wave which radiates from the advancing rotor blade to the acoustic far field (see figure 12).

Simple geometrical constructions can be used to generate qualitative arguments for the general increase in peak pressure level with increasing advancing tip Mach number. At fixed intervals of time, distinct pulses are emitted at the position of the rotor tip and allowed to propagate at the speed of sound in the moving air (see figure 13). In the direction of forward flight, these simulated acoustic waves bunch together, a process that tends to collect and amplify disturbances around the rotor's disc. It can be argued that a shock of strong compression wave is a natural development of this process.

RESEARCH IN PROPULSION

This project consists of basic research, conducted jointly by the Lewis Directorate of AMRDL and Lewis Research Center of NASA, aimed at advancing the technology of propulsion and drive train components and systems. The work is directed toward the solving of special problems involved in the development of small gas turbines (20 lb/sec airflow), and the investigation of advanced concepts in mechanical devices employed in drive trains.

Compressors – Convincing demonstrations of scaling laws can make the extensive technology developed for large compressors available to the designers of small engines. A small axial compressor stage (4.6 inches in diameter) operating at about 1600 ft/sec tip speed demonstrated performance levels within 3 percentage points of a comparable large stage with 49 times as much weight flow. Detailed analysis of the blade element data indicates that minor modification of the flow path and the stators to achieve the design velocity diagrams would eliminate the difference between the two sizes. Severe penalties in performance were noted with increased rotor tip clearances. However, the application of casing treatment recouped approximately one half of the losses. Further investigation of another small rotor with deliberate

missetting of the blade angles showed severe performance penalties emphasizing the necessity for holding close angle tolerances in small axial compressor hardware.

Combustors – An annular combustor of the T-700 size engine is being operated in a research program to provide improved technology for high temperature rise, small combustors. The baseline configuration has been checked out in preparation of evaluating several fuel injector configurations developed during a previous contract. Several experimental combustor liner cooling techniques are also scheduled for evaluation.

Turbines – A three-dimensional, finite-element stress analysis program has been demonstrated for turbine disks and blades. This improved analytical capability can guide designers in developing high temperature, longer life turbines.

RESEARCH IN STRUCTURES

Research in the aircraft structures technology base is, primarily, committed to developing new ways of safely and economically transmitting loads throughout an aircraft with minimum weight penalty. The effort is largely one conducted by the Langley Directorate with support from Watervliet Arsenal.

Analysis/Design of Composite Structures – Most composite structures are designed to operate in the linear elastic range of material behavior. However, as designers confidence grows and requirements dictate, increasing use will be made of the full strength and endurance capabilities of these materials. This will necessitate their use in nonlinear load ranges to satisfy isolated overload and crash survival requirements. Efficient use will require adequate analysis methods. The ability to predict the contemplated loadstrain behavior has been significantly improved in recent years as has the capability to anticipate long-term time-dependent response under loads and residual or curing stress levels, which can influence composite behavior at all load levels. Continuing efforts will be applied to broaden the basic understanding of composite mechanical behavior for any new application.

Composite Materials – It has been recognized for many years that flat ribbon-shaped reinforcing fibers have many advantages over round fibers. They can be made cheaper and have much more to offer in terms of design and fabrication simplicity as well as structural efficiency. However, there are no practical and commercially available ribbon reinforcements. Silicon carbide ribbons of high quality have now been developed by chemical vapor deposition on a graphite ribbon substrate, which was developed for this purpose. Strengths in excess of 300 ksi have been achieved in simple fiber tests. Good strength translation in longitudinal composite tests have been attained. Additional development efforts will be required before this concept can be applied to aircraft structural components.

Adhesive Bonding – Adhesive bonds are widely used to join structural components. Such joints produce milder stress concentrations than do mechanically fastened joints. Hybrid bonded systems of metal and composite layers are stronger for equal weight and stiffness than metals alone. However, under cyclic loading the bond is often the weakest point in a bonded system. Recent work has used strain energy release rate as a parameter to correlate test data on rates of debond between metals and reinforcing composite materials. The specimens were graphite-epoxy bonded to aluminum (with room temperature and elevated temperature cures), and S-glass bonded to aluminum with an elevated temperature cure. Equations, using various algebraic forms that involve strain energy release rate, were fitted to the data. The fit of the empirical forms depended upon the adhesive system, and whether the failure was cohesive or adhesive.

Fatigue Analysis – Fatigue striations in metals are common fatigue features that result from the propagation of fatigue cracks. For constant amplitude loading, each striation is the result of a single load excursion, and, consequently, the distance between striations can frequently be used to calculate local crack growth rates.

Recent experimental results obtained with a scanning electron microscope has discovered that fatigue striations also occur when laminated plates debond under cyclic loading. Figure 14 shows striations in a typical bonded laminate – 7075-T6 aluminum alloy bonded with an adhesive to a unidirectional S-glass composite. The fractographs were made looking toward the adhesive that remained on the debonded aluminum sheet. In the lower picture, two failure mechanisms are indicated by the dark and light surfaces. The dark surface is the result of an interfacial failure between the adhesive and the composite. The interesting features occurred on the smooth interfacial surfaces. A higher magnification of an interfacial failure region (the upper picture) shows striations on the adhesive where the S-glass fibers have cyclically debonded. For this specimen, the striation pitch per cycle was 0.002 mm/cycle, which is very close to the debond rate calculated from the test results, 0.00165 mm/cycle. For the limited results available on other laminate systems, the striation pitch was always within an order of magnitude of the experimentally determined pitch.

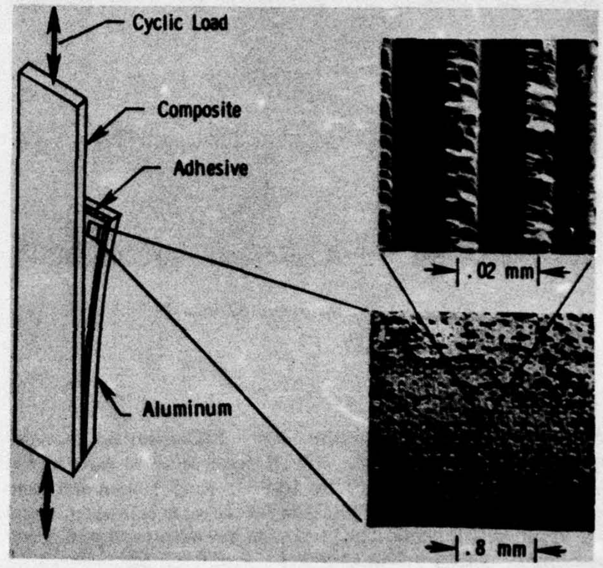

Figure 14. Striations on debonded surface showing fatigue damage.

RESEARCH IN MATHEMATICS

The basic mathematical research efforts of AMRDL are directed, primarily, to the general domain of aerodynamics, propulsion, structures, and decision analysis. The end results of these efforts contribute to fill the technological needs and requirements of advanced airmobile systems. Mathematics and computers are daily tools to research and development efforts. The Laboratory program on mathematical sciences and computing includes research in applied analysis, CAD–E, parallel computation, decision risk analysis, and preliminary design computational methods.

Applied Analysis – Methods for solving transonic small disturbance equations have been developed. These include a variant of an ADI (Alternating Direction Implicit) method which is an order

of magnitude faster than the SOR (Successive Over-Relaxation) method. Applying the ADI method to a difference equation associated with the transonic equation and assuming some reasonable angle of attack variations, a wide range of possible loading variations, can be computed. Figure 15 illustrates a typical result showing a computed lift and moment variation as well as detailed blade surface pressures. The shock motion on the top and bottom surfaces and its effect on the loading are clearly illustrated.

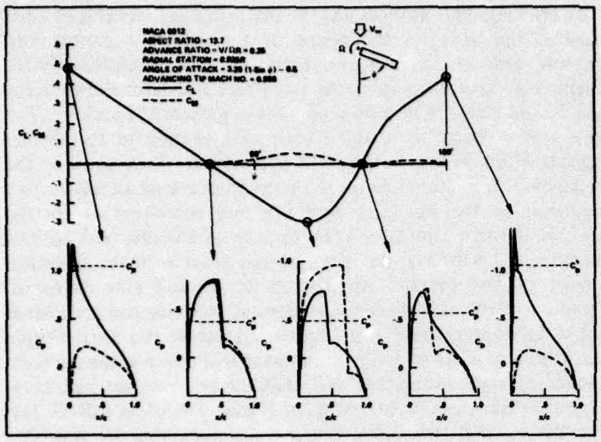

Figure 15. Load variation on a helicopter rotor.

An advanced methodology has been developed to aid in diagnostics of Army aircraft with application during the design process and during operational usage. This methodology utilizes computer analysis and has been breadboarded into a small portable log test set. A mathematical basis for this methodology has been identified and formulated, allowing the intrinsic properties of a complex Logic Model to be studied in an abstract setting. As a result, it was deduced that the minimum number of test points required for conclusive detection of malfunctioning components for a loop-free system is equal to the number of terminal points; this set of points is called terminal set and constitutes the optimal choice for test points.

Also, it was established, for each permutation of the elements in the terminal set, a relative failure probability measure. Based on this probability measure, an optimal diagnostic strategy was defined in accordance with Bellman's Principle of Optimality. For example, figure 16 is a pictorial representation of a logic model where each point depicts a functional entity (component or event) associated with the design of an item or system. The arrows indicate the sense of the functional relationship between the entities. Points 1, 2, and 3 constitute the terminal set. If the diagnostic strategy of this model is to test 2 then 1 then 3, the dashed lines envelop that portion of the overall model or design for which each test point will provide information. Other strategies would induce different probabilities of fault detection at each test point. The objective is to find the preferred strategy for a given design concept.

Operations Research – Bayes decision is a commonly used measure in decision analysis. The common usage is attributable to the fact that it is probably the most intuitive to decision-makers. A Bayes decision can be geometrically represented as a boundary point of the set of all expected loss points. Extensive discussion for the case in which the state space is of finite dimension can be found throughout published literature. A characterization of Bayes decisions was established for spaces of finite as well as infinite dimensional.

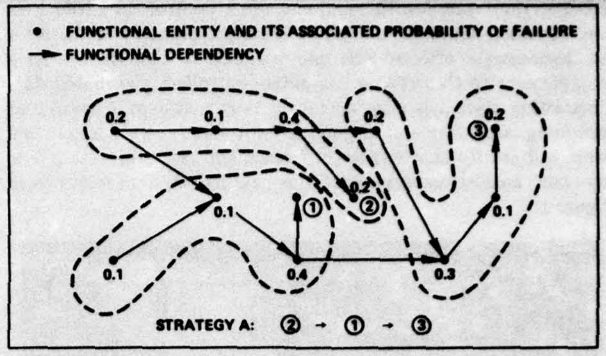

Figure 16. Representative partitioning of a Logic Model as induced by a diagnostic strategy.

AERONAUTICAL TECHNOLOGY – PROGRAM CATEGORY 6.2

AERODYNAMICS TECHNOLOGY

The Laboratory effort in exploratory development of aerodynamics follows the 6.1 technology subdisciplines of fluid mechanics, dynamics, flight control and acoustics and is conducted by the Ames, Eustis, and Langley Directorates.

Controllable Twist Rotor – The CTR concept uses an aerodynamic control surface located on the outboard section of a torsionally-soft rotor blade to vary the twist of the blade collectively and cyclicly. In order to determine the effectiveness of such a system in reducing loads and vibration, a full scale rotor with both conventional and twist control system has been built and whirl tested. Successful wind tunnel tests of the CTR were conducted in the Ames 40- by 80-Foot Wind Tunnel. The configuration of the test blade is shown in figure 17. Preliminary test results show that twist was effectively controlled and that stall boundaries associated with rapid increase in required power were effectively alleviated. Evaluation of data has also indicated that practical application of the CTR principle will require development of an aerodynamically efficient flap system. A swept tip system with an integral flap has been proposed.

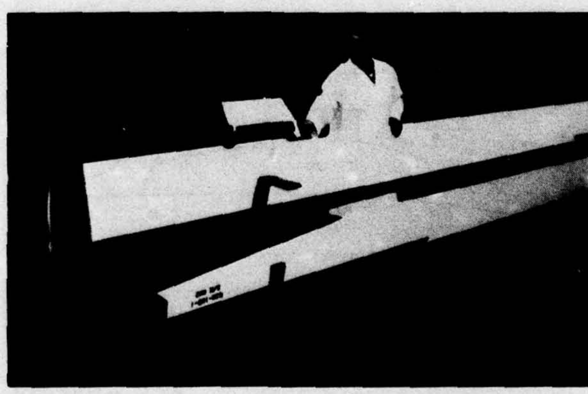

Figure 17. CTR test blade configuration.

Rotor Test Apparatus – The universal helicopter Rotor Test Apparatus (RTA) developed under a joint Army/NASA program, for use in the Ames 40- by 80-Foot Wind Tunnel became operational. The Controllable Twist Rotor was the first advanced rotor configuration to be tested on the RTA. The next configuration will probably be the Multicyclic CTR (MCTR) which introduces

second, third and fourth harmonic pitch control for blade load and vibration suppression. Testing is being conducted on the RTA to demonstrate effectiveness and correlation with theory. As a complement to the RTA, a computer-controlled, distributed data acquisition system is now operational. This system is capable of acquiring, analyzing and displaying static and dynamic data in real time and greatly increases the efficiency and safety of testing. The dynamic analysis subsystem of this new data system is shown in figure 18.

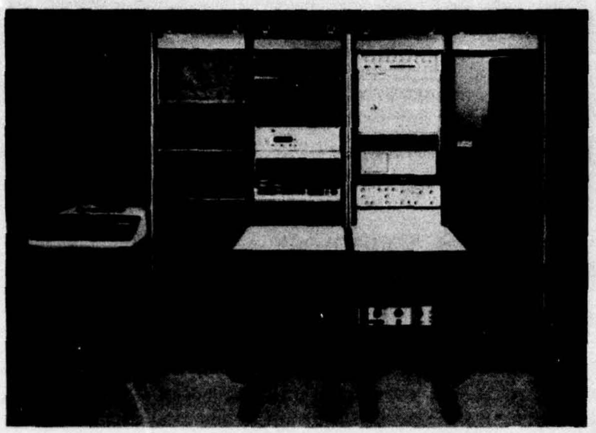

Figure 18. Dynamic analysis subsystem of RTA.

Helicopter Flow Field and Drag – The major source of drag on helicopters is the separated flow in areas of high flow interference. One such area is the region of the pylon, shaft and controls, hub and blade shanks (figure 19) which are comprised of aerodynamically bluff shapes and are not amenable to simple solutions in mathematical analysis. This is due in part to the present non-aerodynamic design of mechanical components in these areas, and partly due to a lack of fundamental knowledge about the complex three-dimensional flow processes which occur around bluff bodies whose flows interfere with one another. Further, there is no systematic information available on the effect of the rotor wake on drag, and on flow separation in particular.

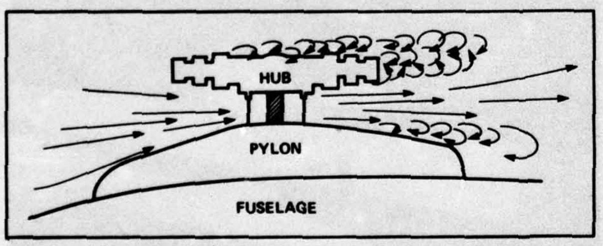

Figure 19. Pictorial representation of mutual interference, turbulence, and flow separation leading to high aerodynamic drag.

Several computational methods are available for synthesizing the flow about arbitrary aerodynamic bodies immersed in a uniform flow, based on potential flow theory, and including viscous effects. Similarly, several computational methods exist for synthesizing the wake of a lifting rotor, both in hover and in forward flight. A recent Laboratory effort combines these two flows, permitting examination of the flow about the hub and blade shanks, drive shaft and controls, pylon, and upper fuselage elements. This provides the design engineer with a realistic and workable flow calculation method which can be successfully integrated into the helicopter design by shaping the elements so as to minimize aerodynamic interference, flow separation, and drag without incurring the costs of wind tunnel testing.

Handling Qualities – The effort to improve the data base on handling qualities is advancing in four areas: analysis, ground simulation, in-flight simulation, and flight test. Mathematical models with rotor flapping dynamics have been developed to facilitate parametric analysis of design parameters important to handling qualities; e.g., hub restraint, hinge offset, pitch-flap coupling, and lock number. This analysis and the mathematical model have been used as the basis for the design of a simulator experiment to explore agility and maneuverability in nap-of-the-earth (NOE) flight. An experiment using the fixed-base simulator shown in figure 20 and a new NOE terrain board is in process of checkout. The new terrain board is a 400:1 scale of a portion of the Hunter Liggett Military Reservation. The plans are to verify some of the fixed-base simulator data on the large-motion-base simulator (see figure 46 in the Facilities Section), and subsequently, on the UH-1H in-flight simulator. The essence of stability and control analysis and handling qualities research is an accurate analytical model of the aircraft. Application of six and nine degree-of-freedom mathematical representations of teetering and articulated rotor helicopters have had limited success in the past. Consequently, a new effort has been initiated to develop advanced techniques of state estimation and stability and control parameter identification from flight test data. Flight tests of an OH-58, performed by Bell Helicopter Textron and supported by AMRDL, show that increasing the rotor inertia (Lock number) has the potential of reducing or even eliminating the restricted portion of the height-velocity envelope, and of allowing a simpler autorotation technique as indicated in figure 21. This work is being extended to obtain a broader understanding of the tradeoffs involved.

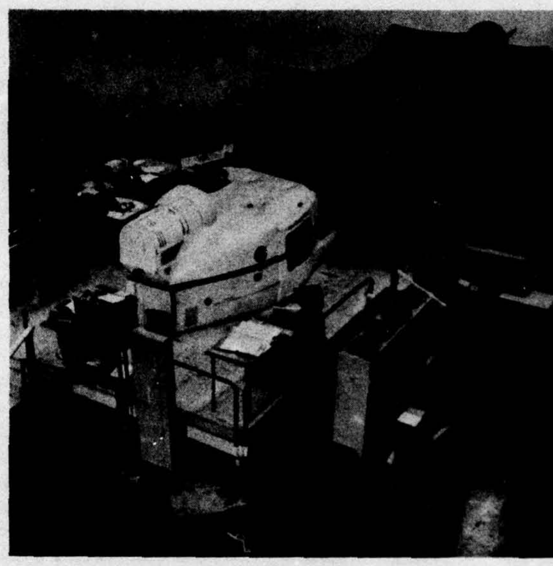

Figure 20. Fixed-base helicopter simulator at Ames Research Center.

Man-in-Loop Simulation – A study was performed in FY75 by AMRDL for DARCOM, to define the Army's R&D simulator needs through the 80's, in support of aircraft development through the 90's. It was found that there was a need for AVSCOM to develop a high confidence simulator not only to support the in-house handling qualities R&D effort, but also to allow total system integration studies during system development. Some of the uses of such an R&D flight simulator are identified in

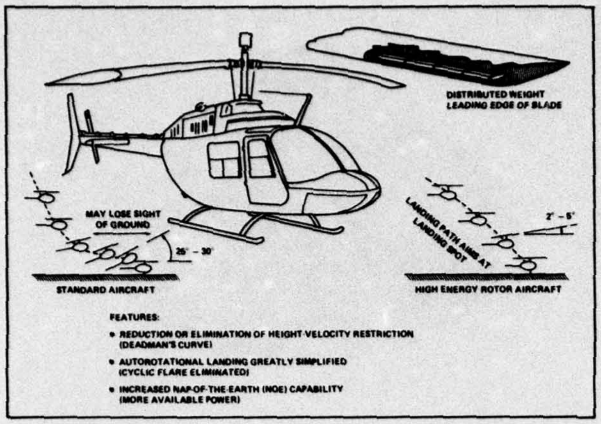

Figure 21. High energy rotor concept.

Table VII. During FY76, a new program was evolved so that in FY77 AMRDL, in joint participation with NASA, will commence development of a new simulation capability. This will be oriented toward the special Army requirement to be able to simulate terrain flying, particularly NOE, and hence, will have a visual display with high detail and wide field-of-view. A sketch of a possible concept of this simulator is shown in figure 22.

TABLE VII. USES FOR AVSCOM R&D SIMULATOR

AVSCOM R&D	• Man-Machine Research • Cockpit Control/Display • Mission Performance • Criterial Specification
PM SUPPORT	• Conceptual Studies • Total System Integration • Competitive Proposal Evaluations • Product Improvement Studies
CONTRACTOR SUPPORT	• Design Development • Flight Test Planning/Familiarization • Envelope Definition/Expansion

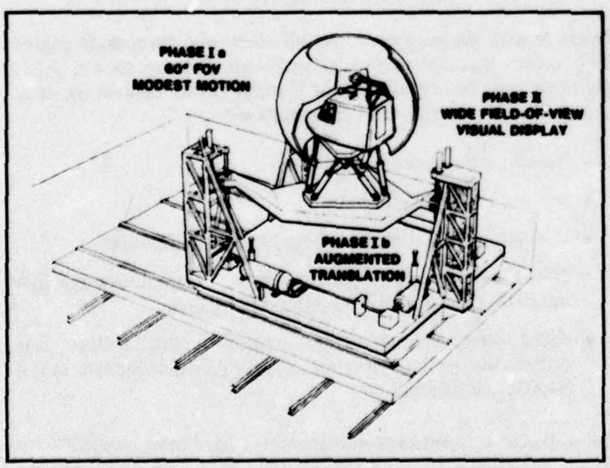

Figure 22. Simulator concept.

STRUCTURES TECHNOLOGY

The 6.2 R&D efforts in structures technology encompass the following subdisciplines of criteria, weight prediction, material engineering, internal/external loads, fatigue and fracture mechanics, and structural concepts. The programs are conducted at the Langley and Eustis Directorates.

AH-1G Helicopter Loads Survey – An aerodynamic and structural loads survey has been successfully conducted through flight testing of an extensively instrumented AH-1G to obtain detailed knowledge of rotor aerodynamic environment and structural response. The development of a rotating frequency-division multiplex, capable of regulating and conditioning over 300 transducer signals, enabled airfoil surface pressures, leading edge stagnation points, local flow magnitudes and directions, blade accelerations, bending moments, acoustic signals, and attendant responses in the control system and airframe to be measured simultaneously. The resulting flight test data has been digitized and is stored on 166 magnetic tapes consisting of 367 recorded channels for 28 hours of flight time. The data may be retrieved for any specific channel and flight condition, and is available to industry and government researchers. The multiplex unit and associated instrumentation is shown in figure 23 and the transducers installed in a typical blade section is shown in figure 24.

Figure 23. Rotating frequency-division multiplex unit installed on rotor hub.

Figure 24. Transducer installation in typical blade section.

Passive Rotor Control – An analytical investigation was conducted to determine the elastic twist needed to optimize the angle of attack distribution to obtain maximum lift to profile torque distribution. In order to achieve as nearly as possible the optimized

angle of attack distribution without using additional controls, an analytical investigation and wind tunnel model test have been conducted to discover and harness the effects of rotor blade planform shape, mass distribution, airfoil characteristics and structural stiffness on the elastic twist of rotor blades.

Bearingless Tail Rotor Loads and Stability – All of the data required to define the structural and aerodynamic characteristics of a bearingless flex-strap tail rotor wind tunnel model and structural data required to define the test stand and drive system were documented. In addition, the physical properties required to describe the various parameters were documented, thus providing a complete description of each configuration tested. The effect of each test parameter on the aeroelastic stability boundaries was shown along with the alternating strap loads where available. A limited amount of analysis was conducted to correlate and to validate the test results.

Fatigue Methodology for Design of Helicopters – Fatigue life estimation of helicopter dynamic components is a complex process that is currently achieved through many different methods. Existing methods used by helicopter manufacturers are quite different in format although they are all based on sound principles. A standardized method that could be used by the Army for reliably predicting component operational life was developed. This method covers areas of mission spectra definition, flight strain survey techniques, laboratory fatigue strength characterization, and safe-life calculation procedures. The major differences in this method and those currently in use is in selecting sample size for laboratory tests for fatigue substantiation. The new method specifies the confidence level as well as the allowed percentage defective for the bench testing of full scale components.

PROPULSION TECHNOLOGY

Technological activities in propulsion, which includes drive trains, covers the development and testing of components of engines and of drive trains. The 6.2 propulsion activities are conducted by the Eustis and Lewis Directorates.

Inlet Protection Devices – A separator scavenge system has been designed and fabricated based on recently established design criteria and design guide technical information. Testing has validated a factor of five improvement in life in an erosive environment over current scavenge systems. This improvement has been demonstrated under test conditions representative of conditions that would be experienced during specification engine sand and dust ingestion testing.

Compressors – The detail design and the fabrication of a hardware for a series of centrifugal compressor stages has been performed as part of the Improved Surge Margin Centrifugal Compressor Program. One configuration is shown in figure 25. The first of a series of nine compressor stage tests was initiated to provide parametric data for the formulation of compressor flow-range and efficiency correlations. The nine tests will use hardware designed for variations in impeller back-sweep (28° and 40°) and internal diffusion or loading coupled with vaneless and vaned diffusers of varying geometric configuration. The testing is facilitated by the use of a variable axial location rotor spindle in conjunction with a capacitance clearance probe in the impeller shroud which permits adjustment of operating clearances while the rotor is turning. The mechanical design of the compressor also permits a quick change of the diffuser configuration without removal of the compressor rotor. The object of the program is to validate a 4-5% improvement in operating line efficiency of high performance single stage centrifugal compressors.

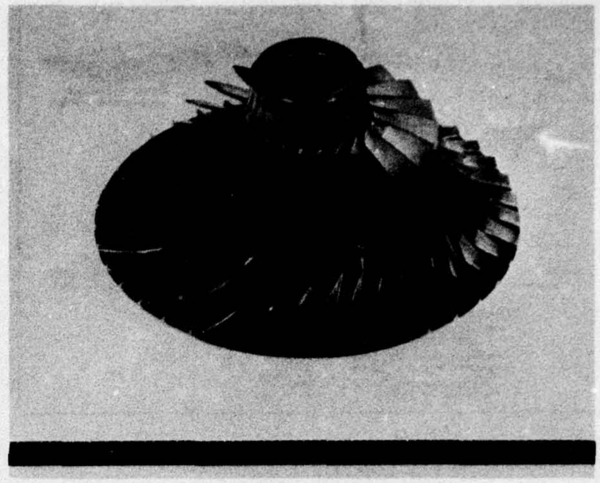

Figure 25. Impeller for Improved Surge Margin Centrifugal Compressor program.

Combustors and Emissions – A combustor design criteria validation program was initiated in July 1975 with the purpose of refining existing combustor analytical design techniques thereby significantly reducing the design and development time cycle of small gas turbine combustors. The program has progressed to the stage, within a one-year period, that the contractor, AiResearch Manufacturing Company of Arizona, has found the application of these computerized design procedures very beneficial in other programs; for example, the TFE-731 turbofan engine redesign, TPE-331 and T-76 update program and the ARPA NAVSEA Ceramic Engine Program. In addition, the NASA T-1 Emissions Reduction Program has benefitted by extensive use of the math models for prediction of emissions and annulus flow properties.

Turbines – Miniaturized laser optic tip clearance probes have been run in both the T-700 and the PLT-34 (Lycoming STAGG) engines. Although data reduction is not complete, it is expected that running tip clearance measurements for two different shroud configurations will be obtained. This program is the first successful measurement of small engine turbine tip clearance during engine operation. The results of the program will provide invaluable information for the design of thermal control shrouds which will allow operation of small engines with reduced turbine clearance. This will improve performance including reduced fuel consumption.

Controls and Accessories – An all electronic turboshaft engine fuel control was operated successfully for 50 hours on a STAGG gas generator. Several significant features of the control, in addition to the electrical system, are as follows:

- Built-in self diagnostic capability.
- Integral electrical alternator.
- Fuel pumping system which operated at 65,000 rpm.
- Direct monitorship of turbine metal temperatures through utilization of miniaturized pyrometer system.
- Field reprogrammable fuel schedules (this feature was utilized during the operation to tailor the fuel schedule to the STAGG gas generator).

Drive Trains – Significant improvements have been identified for Army helicopters through the application of advanced designs, improved materials, and improved manufacturing methods. Several advanced designs of aircraft clutches and couplings have been

investigated to meet the stringent requirements of smaller, higher speed drive systems. Early results from rig testing indicate that the increased requirements can be satisfied with significant weight reductions. NASTRAN techniques have been applied to provide an improved understanding of transmission noise and dynamics. Design procedures will be validated which will result in a significant transmission noise reduction and an increase in life due to reduced vibration.

The Lundburg-Palmgren Theory for predicting life of rolling element bearings has been modified to predict the life of spur and helical gears. This analytical method will provide helicopter designers with a tool for developing transmissions with longer lives.

RELIABILITY AND MAINTAINABILITY

The basic R&D effort in this area is to conduct those exploratory development programs necessary to define the relationship between R&M quantitative characteristics and system, subsystem, and component design criteria/arrangements and test requirements. The 6.2 R&M effort is conducted by the Eustis and Lewis Directorates.

ARMS Model for UTTAS COEA – The AMRDL developed ARMS (Aircraft Reliability and Maintainability Simulation) Model was chosen by the TRADOC Systems Analysis Activity (TRASANA) located at White Sands Proving Ground to analyze the comparative performance effectiveness of viable candidates for the UTTAS mission in a Cost and Operational Effectiveness Analysis (COEA). This analysis is preparatory for the UTTAS limited production decision by HQDA and DOD. For this task AMRDL constructed and validated ARMS Models of the UH-1H, UH-1N, Bell 214, Boeing UTTAS, Sikorsky UTTAS, and a composite Government version of a production UTTAS. Simulation runs representing two geographical areas and several mission tasks were processed for this analysis.

Diagnostic Logic Model Test Set – Based on previous AMRDL investigations which developed the techniques for generating complex logic models by computer, work was initiated on a breadboard design of a logic model (LOGMOD) test set which will allow aircraft technicians to perform sophisticated diagnostic and troubleshooting procedures in a simple and rapid manner on a variety of aircraft subsystems. Through the use of a visual readout and a small hand-held keyboard as shown in figure 26, the technician is immediately informed of the exact test procedure to follow based on the functional design logic of the component being tested and the test results observed at each step of the diagnosis. The test set weighs less than 40 pounds and will be usable at all levels of maintenance. The Air Force Human Resources Laboratory and the PRAM Office at Wright-Patterson Air Force Base have indicated interest in this test procedure and plan to investigate its use in FY77 in cooperation with AMRDL.

Ground Base Reliability Testing – A recently completed effort under the R&M program was the feasibility demonstration of system reliability testing through structural dynamics as depicted in figure 27. This concept establishes a ground-based test method which duplicates the full spectrum of in-flight vibratory loads at a fraction of the cost of in-flight testing. Proposed concept demonstration through the use of full-scale hardware is scheduled for the FY77-78 time period. This advanced concept will be used to support both the AAH and ASH aircraft programs. Mission equipment integration will be one of the major payoff areas where this ground-based helicopter vibration testing will be used.

Superhard Canopy Coating – The development of superhard coating for full-scale UH-1 type acrylic windscreen has been successfully

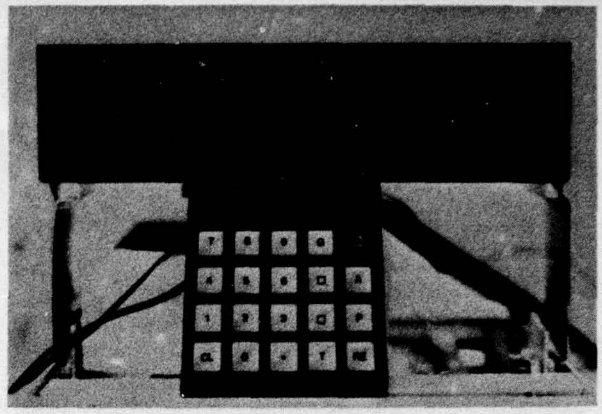

Figure 26. LOGMOD display and keyboard.

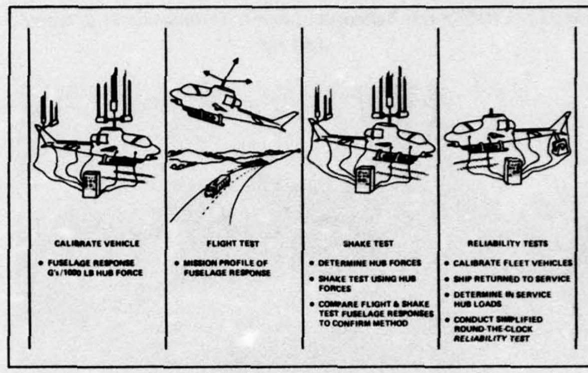

Figure 27. System reliability tests through structural dynamics.

demonstrated with good adhesion and high abrasion resistance characteristics without degradation of optical properties. Hardness equal to or greater than glass was obtained. Additional testing is in process to fully establish the coating properties. Application of this technology will greatly reduce the cost of canopy repair and extend the useful operating life.

SAFETY AND SURVIVABILITY

Safety and survivability technological development effort is presently directed toward the development of techniques for defeating or degrading the effect of known or potential threat weapons and target acquisition devices through aircraft signature reduction and aircraft design, weapon effectiveness reduction, and vulnerability reduction. The development efforts are conducted by the Eustis Directorate.

Flight Safety – CH-47 Crash Test II, follow-on to the FY75 Crash Test Program, utilizing a recently retired, structurally sound CH-47A was conducted on 4 August 1976, see figures 28 and 29. The test vehicle included cargo restraint, crew restraint, and structural experiments incorporating a total of 126 channels for data recording. By obtaining technical data on the behavior of large helicopter structures and components in the crash environment, design criteria can be developed and/or improved which will enhance the crashworthiness and mission capability of future Army aircraft. A final report on this test will be published. Test data will also be used to improve a computer program termed KRASH, an analytical model for predicting the dynamic structural response of helicopters in a crash.

Crashworthy Troop Seats – Two years of troop seat R&D efforts culminated in the successful dynamic testing of several experimental models at the FAA's Civil Aeromedical Institute in

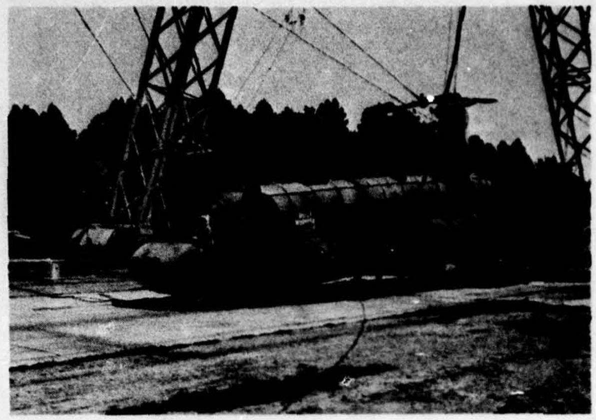

Figure 28. CH-47A test helicopter prior to installation in dynamics test rig.

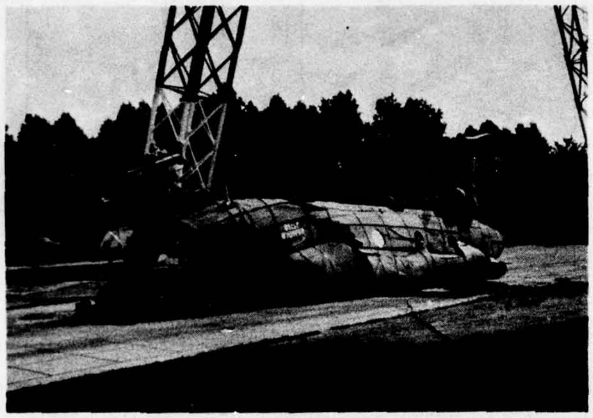

Figure 29. CH-47A crash test.

Oklahoma City, Oklahoma. The seats were subjected to testing criteria which were contained in a draft military specification soon to be coordinated among selected Government agencies for subsequent publication.

UTTAS Seat Testing – Several representative troop and gunners seats, figure 30, from both UTTAS competitive entries were procured and subjected to rigid dynamic test requirements by the Naval Air Development Center in a joint Army/Navy program. In all cases, initial testing resulted in seat failure. Subsequent design modifications and retest were more successful, but additional effort is necessary if the seats are to meet Crash Survival Design Guide and draft Military Specification criteria.

Ballistic Protection – Laboratory testing of a conventional CH-47 mechanical flight control system mated to a single channel fly-by-wire backup system as illustrated in figure 31 was successfully operated in parallel without any interface problems. In other actions, an evaluation has been conducted on 14.5 mm and 23 mm crew armor kits for the AH-1G/Q and OV-1D aircraft establishing more effective crew protection design criteria for such threats, and a preliminary fuel system design concept against the 23 mm HEI-T projectile threat has been established with consideration for low cost, weight, RAM and crash protection factors.

Signature Reduction – The air mixer concept was integrated into a combination hot parts and exhaust plume suppressor design. Hardware is in fabrication and will be flight demonstrated and evaluated for effectiveness.

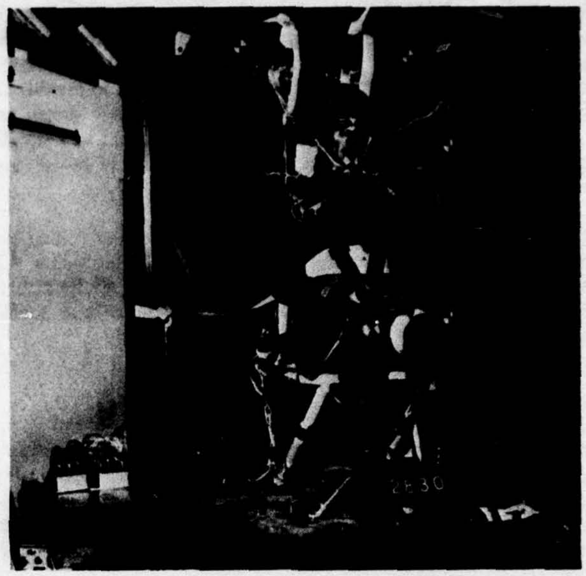

Figure 30. UTTAS troop/gunner seat test rig.

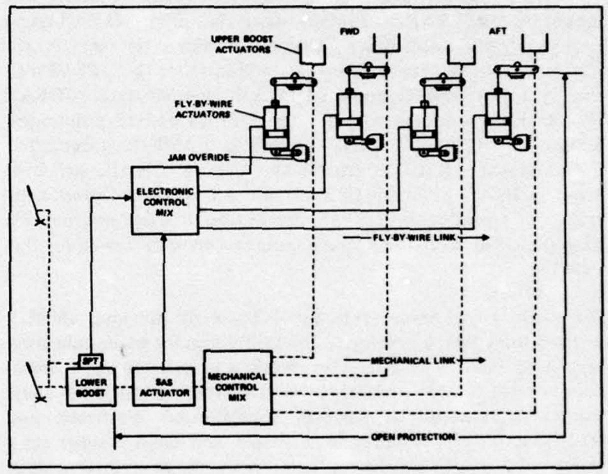

Figure 31. CH-47C backup flight control system block diagram.

Initial development of an analytical procedure for prediction of the radar cross section (RCS) of helicopters has been completed. Several low RCS designs of helicopter fuselages were completed and RCS analysis initiated. Static RCS measurements of the AH-1G low RCS MRB were completed. Reduction of the RCS of the AH-1G main rotor hub as well as reduction of visual signature was initiated.

The study and analysis of laser countermeasures for application to the AH-1G helicopter was initiated. Resultant hardware concepts will be fabricated and evaluated.

Vulnerability Reduction – The Eustis Directorate has assumed technical and contractual responsibility for the vulnerability reduction (VR) portion of the Aircraft Survivability Equipment program. Vulnerability reduction, by definition is the enhancement of aircraft design in a manner that reduces the aircraft's susceptibility to damage when subjected to threat mechanisms. Within the current fleet of operational Army helicopters, the OH-58 and AH-1 have the longest service life remaining. Therefore, vulnerability reduction efforts will be concentrated on these

two aircraft. The threats considered as the basis for these VR efforts are the 7.62 mm, 12.7 mm, 23 mm API, and 23 mm HEI.

During most of FY75, considerable effort was expended on defining the VR efforts which should be pursued, specifically the OH-58C and AH-1S flight control systems and transmissions. To this end, the following tasks were started.

OH-58C: A contract was awarded during February 1976 for the design, fabrication and testing of VR modifications to the OH-58 flight control system. It will improve the structural integrity of the cyclic and collective control systems as well as provide a back-up cable system for the directional control system. During June 1976 this contract was modified to include VR modifications to the OH-58 transmission. It will qualify a four planet, planetary transmission to be installed in the OH-58C. Furthermore, design support tests will be accomplished to optimize the transmission lubrication/cooling system, improve the shaft input seal and improve the rotor shaft bearing.

AH-1S: A VR transmission program was begun in October 1975 to determine if the VR, no-lube goals for the transmission could be met with only internal changes instead of having to provide an auxiliary lubrication system. In the flight controls area a program was initiated in June 1976 to validate both the feasibility and the applicability of a triplex, fly-by-wire, directional control system for the AH-1S helicopter. If the results confirm concept feasibility and acceptability as an AH-1 survivability modification and also show potential improvements in other areas such as weight, cost and reliability then, a follow-on program would be initiated to prototype, flight test and qualify hardware for the production "S" and for a retrofit kit to the "Mod S" AH-1 helicopters.

MISSION SUPPORT

Mission support technological development effort is directed toward the equipment which will enhance the effectiveness of military operational capabilities of Army aircraft, particularly in the forward areas. This effort is conducted by the Eustis Directorate.

Cargo Handling – Army aviation mid-intensity warfare doctrine for the high air defense threat environment envisions the utilization of helicopters in supply/resupply missions requiring terrain flying flight profiles. This new doctrine represents a major departure from current techniques and it will require the exploration of innovative approaches to allow expeditious delivery of internally and externally carried loads. Both the CH-47 and UTTAS helicopters are being studied. The ability of these helicopters to transport external loads to forward areas and conform to the necessary terrain flying mode is being assessed through simulation of the airframe and associated external load to determine the height, speed and maneuver load factors as well as safety implications. Data are being collected and analyzed to provide capability improvements for identified limitations. Both aircraft are also being studied to determine their limitations in transporting internally carried loads. The objective of these studies is to minimize turnaround time. All elements of cargo loading, unloading and restraint operations are being analyzed to identify performance/productivity improving concepts. In this connection, a full-scale cargo restraint experiment was conducted in conjunction with the crash test of a CH-47 aircraft, figure 32. Side by side wheeled and palletized typical loads were restrained conventionally and with energy absorbers. Results are being analyzed to establish basis for reductions in the amount of restraints, the time for restraining operations and improved safety.

Ground Support Equipment – Concept formulation, selection and definition studies are being conducted for helicopter ground mobility systems for the AAH and UTTAS aircraft with adaptability to skid equipped aircraft. The objective of this effort is a highly air and ground mobile device(s) which provides rough terrain ground mobility to tactical helicopters for combat area concealment and maintenance purposes. A concurrent and similar study is being conducted for an aircraft ground power unit which will provide all necessary ground power for AAH, UTTAS, and CH-47 helicopters from one compact, lightweight and high mobile ground unit. The program includes design and fabrication of engineered models for concept evaluation testing by appropriate Army agencies.

Figure 32. Aft pallet tie-down installation – CH-47 crash test.

AIRCRAFT SYSTEMS SYNTHESIS

Aircraft systems synthesis has as its objectives the development of a unified and coordinated R&D program to effectively and efficiently meet Army aviation requirements and DA science and technology objectives. The overall approach involves:

- Analysis of Army aviation systems, analysis of advanced air vehicle concepts, and coordination with TRADOC and other DARCOM commands to ascertain and define the needs and requirements of future airmobile systems.
- Identification of airmobile technology voids through continued assessment of the state-of-the-art in both domestic and foreign technology, and through technology forecasting.
- On the basis of the above information, effect an RDT&E program balanced to eliminate critical technology voids and to meet Army aviation requirements through a consistent resource allocation policy.

This effort is primarily accomplished by the Advanced Systems Research Office, AMRDL Headquarters, and the Systems Research Integration Office, St. Louis. Some preliminary design support is provided by the Eustis Directorate.

Brief descriptions of technical accomplishments for FY76 and FY7T are presented in Table VIII.

AIRCRAFT SUBSYSTEMS

This project is a new start in FY76 which will provide visibility to the technological development efforts of aircraft subsystems that have been overshadowed in the past by subsystem R&M programs and/or off-the-shelf equipment. The objective of the project is to advance the state-of-the-art for Army aircraft subsystems such that significant improvements in operational effectiveness and/or reduction in life cycle costs can be achieved.

TABLE VIII. AIRCRAFT SYSTEM SYNTHESIS MAJOR FY76/7T ACCOMPLISHMENTS.

AREAS OF EFFORT	FY 76/7T ACCOMPLISHMENTS
EVALUATION OF ADVANCED AIRCRAFT CONCEPTS	• Refined and expanded PSDE programs • Exercised performance estimation program in support of the following: UTTAS SSEB AAH Project Manager Weapons System Manager Aircraft Survivability Equipment Project Manager • Supported ASH Project Manager in aircraft design evaluation and man-machine interface study • Coordinated program assessment by AQUILA Review Team • Compared special properties of ABC, compound and pure helicopter, to Army requirements
ANALYSIS OF ARMY AVIATION R&D PROGRAMS	• Conducted technology impact assessments for: LLNO requirements Aviation engineering psychology Modular weapons Technology advances in structures Technology advances in propulsion Nondestructive testing methods • Conducted technical risk analyses for: RPV AH-1Q Improved Main Rotor Blade Integrated Helicopter Flight Controller RSRA OH-58A Main Rotor Mast
ORDERLY PLANNING & PROGRAMMING OF ARMY AVIATION R&D	• Prepared feasibility studies for helicopter commonality review (HELCOM) • Defined AVSCOM simulator requirements • Completed 5th edition of Army Aviation RDT&E Plan • Published Laboratory SPF/SPEF Reports • Initiated program to increase mathematical sophistication in in-house computer programs and applications
FOCAL POINT FOR ARMY AIRMOBILE R&D	• Conducted RPV Supporting Technology Symposium • Evaluated industry and university R&D proposals

Nickel-Cadmium Battery – The Ni-Cad battery has a history of explosions, fires, and accidents in the fleet of Army aircraft. This battery is best suited to a constant current type of charge and the Army application has always used the battery directly on a constant voltage buss. Aging or unbalanced cells, excessive compartment temperatures, and poor maintenance can increase the probability of thermal runaway of the Ni-Cad with resulting battery destruction and possible in-flight fires. There are several well-documented aircraft losses caused by Ni-Cad battery failures.

An interface unit between the battery and aircraft dc buss was investigated under contract with Chrysler Aerospace and proved successful in preventing thermal runaway and reducing battery maintenance requirements.

A BIU (Battery Interface Unit) is presently being investigated which will have universal application to all aircraft with NI-Cad batteries. Three flight configuration prototypes will be built and tested to verify the application and concepts. These units will be capable of operation from either an ac or dc electrical system.

Helicopter Ice Protection – R&D efforts to date have established meteorological ice protection design criteria for helicopters and has concluded that technology capable of providing satisfactory ice protection systems for current and future Army helicopters exists with the exception of rotor blade protection. Weight penalties attendant with rotor blade ice protection are significant for large helicopters and prohibitive for smaller helicopters such as the OH-58, AH-1G, and UH-1H. In an effort to overcome this technology void, R&D efforts were initiated in FY76 to investigate the feasibility of microwave and vibratory rotor blade ice protection concepts. These concepts offer significant reductions in ice protection system weight. However, significant R&D efforts will be required to develop these concepts into operational systems.

RPV SUPPORTING TECHNOLOGY

Exploratory development efforts for remotely piloted vehicles did not exist within AMRDL prior to FY76. The 6.2 RPV activities are conducted by the Eustis Directorate; the programs seek to eliminate the technological voids in air mobility which hamper the development of mini-RPVs (less than 200 pounds) for military applications. The key air mobility disciplines necessary to the development of mini-RPVs are: propulsion, launch and recovery, survivability/vulnerability, RPV configuration, structures and flight control. The AQUILA System Technology Demonstrator, shown in figure 33, is the primary advanced development program for mini-RPVs.

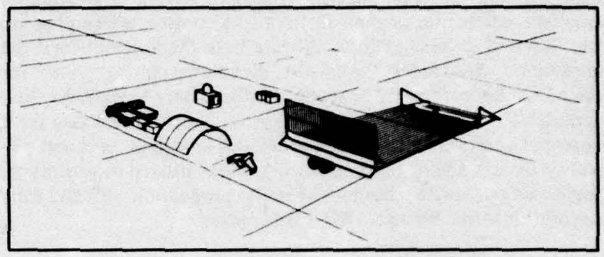

Figure 33. AQUILA system.

Propulsion – Several candidate mini-RPV engines have been purchased and have been tested and evaluated at MERADCOM, Ft. Belvoir, Virginia. These efforts include performance and durability tests as well as studies to determine suitable oils and fuels for two cycle engines. AMRDL-Eustis hosted inter-service mini-RPV propulsion meetings in June 1975 and June 1976. A design study effort for small propellers for mini-RPVs was initiated in FY76. An information and planning letter was sent to both foreign and domestic sources, as well as being published in the Commerce Business Daily. These efforts should help identify engine development activities within industry which might yield mini-RPV propulsion applications.

Launch and Recovery – Coordination began, and is continuing with industry and government on a variety of recovery options – parachute, parafoil, landing systems, horizontal and/or vertical net systems, and low pressure air inflated structures. A five month recovery systems study effort and an alternate "AQUILA type" recovery system demonstration contract were awarded.

Survivability/Vulnerability – Test data on the survivability of mini-RPVs and computer simulations for RPVs of varying radar cross sections flying against a variety of threats were analyzed. Vulnerability testing of an AQUILA wing panel to 23 mm HEI was conducted at Eustis.

RPV Configuration – An in-house developed computer program for forward flight has been completed and excellent correlation with existing RPVs was obtained. Propeller and two cycle engine performance routines are nearly finalized.

Structures – A contract was awarded to investigate the applicability of advanced structural concepts (space-wind) to mini-RPVs. Coordination on manufacturing materials and techniques was

begun and will continue with other services, and the Air force in particular.

Flight Control – A family of electromechanical actuators suitable for mini-RPV usage is being designed for fabrication and qualification testing. A contract study of flight test data investigating characteristics of the atmospheric electric field (for application to electrostatic autopilots) was completed.

AIRCRAFT WEAPON TECHNOLOGY

The Army aircraft weaponization program provides the capability of delivering ordnance to destroy, neutralize, or suppress those targets jeopardizing ground or airborne forces in the conduct of the land combat role. This capability depends on the adequacy and timeliness of the aircraft weapons technology. Within the AVSCOM mission requirement to develop aviation systems, including the interface of aircraft subsystems and aerial armament subsystems, AMRDL has the responsibility to advance the technological base for aircraft weaponization applications. Primary performing Army activities for R&D of aerial armament subsystems include the ARMCOM and MICOM.

Precision Gun Point and Constant Recoil – Aircraft gun weapon effectiveness can be improved by gun station stabilization and reducing the effects of varying recoil forces on the aircraft structure. Detailed analyses of the control system in the XM97 turret has resulted in a much better understanding of its capabilities/deficiencies. Control improvements to include accommodation of the disturbances expected in the field environment have been defined. A contract was awarded in FY76 for the functional design of a precision pointing and stabilization system to be tested on a modified XM97 test bed system in the future. Sensitivity analyses using a system performance aircraft weapons model have been used to measure the relative importance of system components in an aircraft gun system. A detailed model of the Cobra aircraft structural flexure under firing conditions is included in the performance model, and the advantages of constant recoil operation have been analytically quantified. Constant recoil hardware work has continued, and the hydraulic constant recoil hardware developed by Honeywell is being flight tested. Present efforts to define a hybrid constant recoil approach will combine the best attributes of hydraulic and electro/mechanical implementation techniques. The level of recoil force attenuation attainable is indicated in figure 34. Stabilization and control work combined with recoil attenuation techniques are critical features in implementing a long range point target gun system on an airframe.

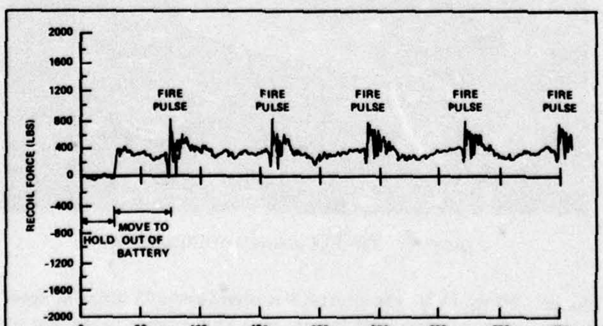

Figure 34. Constant recoil.

Automatic Target Cueing – An automatic target cueing system (AUTOCUE) as shown in figure 35 schematic, has been checked out in a laboratory environment. FLIR data tapes were used to simulate scene presentations from the aerial platform. The AUTOCUE frame rate exceeds one per second, and a dramatic increase in target acquisition and identification capability was obtained. The operator in the normal search mode misses many targets in the field of view even if he has several seconds of dedicated observation time. The AUTOCUE system provides an audible cue and a visual position cue superimposed on the display for the majority of targets presented.

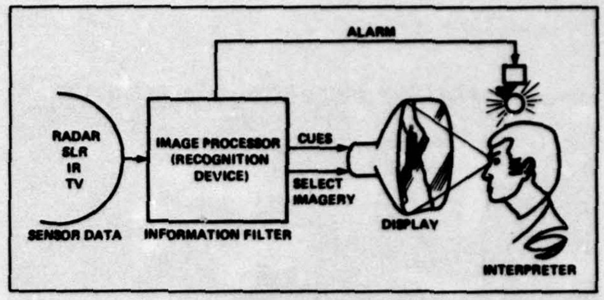

Figure 35. Automatic cueing system.

Common Ammunition and Gun Technology Test Bed – Efforts to define design and development responses to commonality requirements in the three services are proceeding. Advanced ammunition configuration alternatives having potential for satisfying common gun/ammunition requirements are being evaluated and will be compared with conventional approaches. The ammunition configurations addressed are cylindrical cased telescoped, folded (rectangular), separate loading ammunition, and conventional. For each ammunition option considered, data are being obtained which characterize the interior ballistics and performance envelope of the particular cartridge geometry. Emphasis is on obtaining gun/ammunition interface data as a prerequisite to gun design concepting efforts. A common Gun Master Plan is being formulated and staffed, with funding support from other projects as well. The *objective is to foster the use of a particular ammunition and gun* subsystem in various mission and service roles.

ADVANCED TECHNOLOGY DEMONSTRATION – PROGRAM CATEGORY 6.3

TILT–ROTOR RESEARCH AIRCRAFT

This is a joint Army-NASA program to demonstrate advanced technology pertaining to tilt-rotor aircraft concept. The goal is to achieve the speed and economy of fixed-wing turboprop aircraft combined with the VTOL capability of modern helicopters.

The first phase of the plan, completed in FY73, covered competitive design by two contractors. The second phase, now underway, covers the completion of detail design, fabrication and test of the aircraft by a single contractor, Bell Helicopter Textron. A program of supporting technology research, necessary to reduce the risk of developing the research aircraft, includes model and full-scale component wind tunnel testing and flight simulation investigations.

During FY76 engine acceptance tests, canopy proof load, canopy ballistic jettison, and ejection seat ballistic tests were completed. In addition, bench tests of the transmission and engine coupling gear box as well as testing most other major components has been accomplished. During May 1976, Aircraft No. 1 (figure 36), was transported to the Bell Flight Test Facility for completion of assembly and preparation for the Integrated Systems Test. Aircraft No. 1 should rollout in the first quarter FY77, followed by first hover flight and Ames 40- by 80-Foot Wind Tunnel testing. Aircraft No. 2 will be completed during FY77 and both aircraft will be available for contractor and military flight tests during FY78.

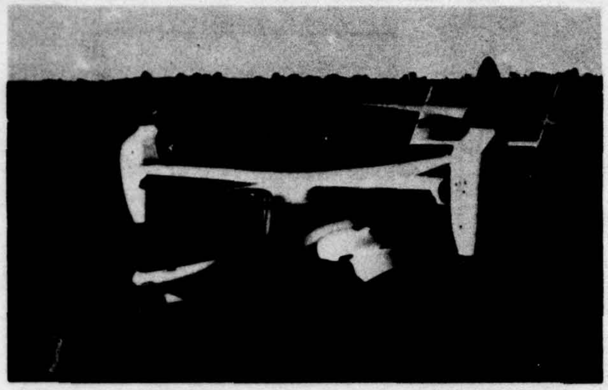

Figure 36. XV-15 Aircraft No. 1.

ROTOR SYSTEM RESEARCH AIRCRAFT

The RSRA program. A joint Army/NASA effort, will provide flight research capability to accomplish the following:

- Evaluate the potential of promising new advanced rotor concepts.
- Verification of numerous areas of supporting research technologies.
- Tests of product improvement rotors.

Under contract, Sikorsky Aircraft has completed fabrication of the first aircraft and the second aircraft is 95 percent complete. Figure 37 shows the first aircraft in the helicopter configuration during the recent roll-out ceremony. The second aircraft will initially have a variable incidence wing and auxiliary propulsion engines. These features, interchangeable between the two aircraft, will provide a rotor research envelope from 0–300 knots as well as negative and positive g's in level flight. Design and component tests of the emergency escape system are nearly complete with full-up system tests scheduled on the Holloman Air Force sled track in September. First flight of the RSRA in the helicopter configuration will occur during the first part of October.

Figure 37. RSRA in helicopter configuration.

ADVANCED ROTOR TECHNOLOGY

Bearingless Main Rotor Concept – A competitive procurement was conducted to design, fabricate and test a main rotor that will have no bearings, no lead/lag hinges and will utilize a flexbeam type construction to accommodate control system pitch inputs (through beam torsional deflection) and normal flapping motion (through beam bending). The use of composites, no bearings, and no hinges will provide major advances in R&M for helicopters incorporating this concept (see figure 38).

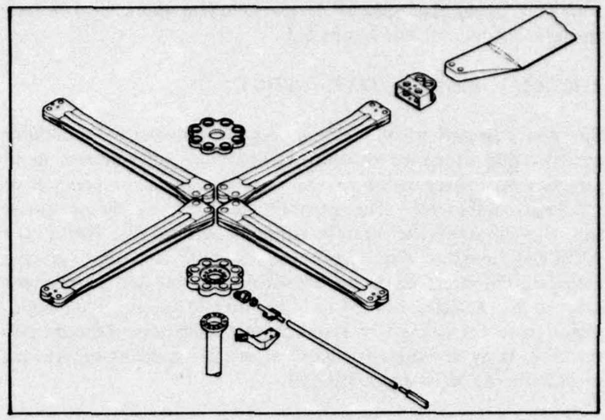

Figure 38. Exploded assembly of Bearingless Main Rotor concept.

As a result of this competitive procurement, Boeing-Vertol will conduct the program and perform a twenty-five (25) hour flight test program on a BO-105 helicopter. The flight tests are scheduled to begin in May 1979 and it is anticipated that the results of these tests will demonstrate the feasibility of the Bearingless Main Rotor (BMR) concept.

Advancing Blade Concept – The Advancing Blade Concept (ABC) is a coaxial, counterrotating, hingeless rotor system, which offers several potential advantages over conventional rotor systems. With this concept, the problems of retreating blade stall are largely eliminated and maneuver capability significantly enhanced. Substantial improvements in maintainability are projected, since the need for a tail rotor is eliminated and the main rotors are hingeless. The program is under contract to Sikorsky Aircraft and the ABC aircraft configuration (XH-59A) is shown in figure 39.

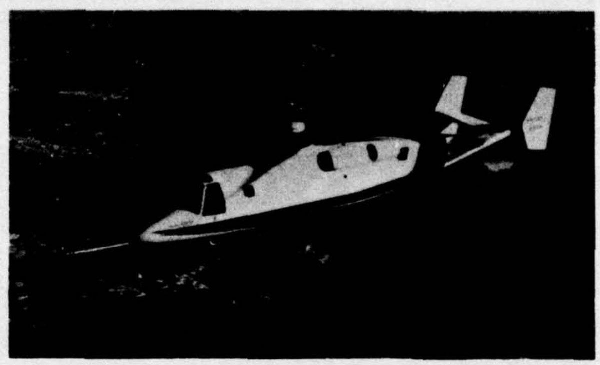

Figure 39. XH-59A aircraft configuration.

As of 16 July 1976, the aircraft has been flown 45 hours at speeds up to 196 knots and load factors to 2.55 g. Flight-testing has confirmed advantages of this concept and identified some shortcomings. Blade stall boundaries were encountered only at high advance ratios and high altitudes. The aircraft demonstrated rapid control response about all three axes with a minimum of cross-coupling. The benefit of not having to power a tail rotor was verified during hover performance. A low noise signature, attributed to a relatively low blade tip speed and lack of a tail rotor was noted. Structural loads in the rotor and control system ranged

from low to moderate indicating potential for substantial weight reduction. Weak directional control power in partial power descents and autorotation was observed. Demonstration of autorotational capability including investigation of the vortex-ring state, flare techniques, and ways to improve directional control at low collective settings and high flare angles is currently the program scheduled priority items.

Second Generation Comprehensive Helicopter Analysis System – The objective of this R&D task is the development and demonstration of an analytical model to accurately predict the aeroelastic stability, stability and control, performance, loads and acoustics characteristics of rotary wing aircraft. Once developed, the system will reduce engineering development cost and risk for new helicopters, prevent delay in deployment of new aircraft, provide the Army with a reliable evaluation tool, reduce reliability, maintainability and safety problems of operational aircraft, and solve technical problems restricting operational capabilities. The system will also provide propulsion system/airframe compatibility to improve the aircraft propulsion system. A Government/Industry working group has been established to prepare the functional specification for the system and to define the approach to be taken. A major amount of the work will be done under contract to helicopter manufacturers, software firms, and educational institutions. The system, once developed, will be validated by correlation with experimental data.

ADVANCED AIRCRAFT STRUCTURES

Multi-Tubular Spar – The all composite multi-tubular spar (MTS) AH-1G main rotor blade program has the following design objectives:

- Improved 23 mm HEI ballistic damage tolerance.
- Reduced radar cross-section signature.
- Improved fatigue life.
- Direct replacement for the 540 main rotor blade on the AH-1G helicopter.

Cross-section detail of the root end of the blade is shown in figure 40. Many of the blade components were fabricated utilizing the wet filament wound technique, followed by co-curing of the components in a mold. The s-glass leading edge longos, the Kevlar-49 spar tubes, and the Kevlar-49 spar cap longos are the primary load carrying members, and each one is individually capable of reacting maximum centrifugal force. The 540's hub attachment configuration has been duplicated by wrapping the leading edge glass unidirectional longos, the Kevlar leading edge and the Kevlar "broom" around the main pin bushing; and the graphite trailing edge longos around the drag brace pin bushing. Fabrication of all MTS blades has been completed and specimens of the subject blades have successfully undergone radar, ballistic, dynamic, stiffness, and tip start/stop testing. Two MTS specimens have undergone both root-end and mid-span fatigue testing at 130 percent of maximum level flight loads, with each specimen accumulating 2 million cycles. Two more fatigue tests are scheduled, one with a virgin specimen and the other with 23 mm HEI ballistic damage to the leading edge. The ground whirl and flight tests are scheduled to be completed in the first quarter of FY77.

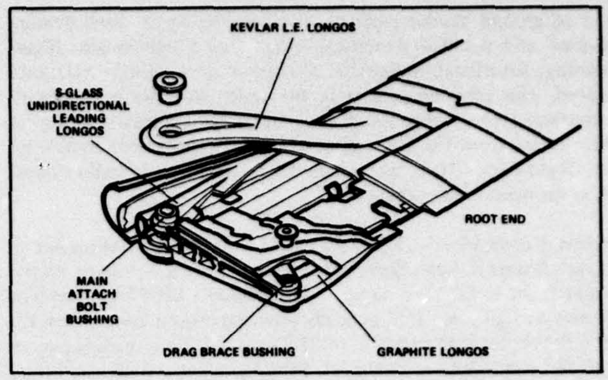

Figure 40. Multi-Tubular Spar AH-1G main rotor blade root end.

PROPULSION

Small Turbine Advanced Gas Generator – The STAGG program objective, development of gas generator technology for advanced aircraft engines and auxiliary power units (APU) in the 200 HP to 800 HP range, has been successfully completed in FY76 with all technical objectives met or exceeded. These technical objectives, as compared to current production engines were:

- 20–30 percent improvement in specific fuel consumption.
- 35–40 percent increase in specific horsepower.

Technology from the STAGG program has been incorporated, to date, into the Air Force A-10 aircraft APU and the Army 30 kW generator set.

800 HP Advanced Technology Demonstrator Engine – Program approval for the 800 HP Advanced Technology Demonstrator Engine (ATDE) was obtained during FY76 and proposal evaluation was initiated during FY7T. The objective of the program is to demonstrate an advanced turboshaft engine having the following significant improvements in performance, capability, and cost:

- Decreased specific fuel consumption by 17–20 percent.
- Increased horsepower per pound of engine inlet airflow by 25–35 percent.
- Decreased vulnerability.
- Improved producibility, RAM, and survivability.

This will be accomplished by development and testing of an 800 shaft horsepower ATDE incorporating advanced components and gas generator technology.

RELIABILITY AND MAINTAINABILITY

Oil Debris Monitoring Evaluation – A program to monitor oil borne debris generated by helicopter engines and transmissions was initiated January 1975. The program's objective is to develop an effective oil debris analysis technique that will augment the current Army Spectrometric Oil Analysis Program. During the course of the program every component that is removed will be cycled through the teardown evaluation section of the Corpus Christi Army Depot. The information gathered will be analyzed for correlation between component condition and the debris analyzed by the various techniques under investigation. The techniques under investigation are ferrography, particle size distribution, oil turbidity, scanning electron microscopy and also spectroscopy. Another facet of the program is the investigation of ultra fine filtration on the debris monitoring techniques. Seven of the twenty-three aircraft supplying data have been outfitted with 3 micron oil filters.

CARGO HANDLING EQUIPMENT

Cargo Acquisition – The technical feasibility of a helicopter transported Container Handling Device (CHD) for acquiring, transporting, and delivering standard 8X20-foot containers without the

aid of ground handling personnel or prerigging has been demonstrated and detailed structural designs for a lightweight, flightworthy, functional, militarized-configured device (MIL-CHD) produced. This program is now in the design stage for all necessary interfacing components and subsystems for supplying power to the device from the helicopter and for its functional control by the flight crew. The program includes fabrication and flight evaluation for operational validation.

Cargo Stabilization – The AAELSS II, a second generation Active Army External Load Stabilization System for helicopters, underwent flight test evaluation while installed on a CH-47 helicopter as shown in figure 41. Hydraulically powered arms mounted beneath the helicopter automatically control load motion providing pendular damping levels in excess of the 25 percent critical condition. The system completely eliminated longitudinal pilot induced oscillation (PIO) tendencies, permitting full envelope Instrument Flight Rules (IFR) flight with heavy external payloads. The evaluation showed that the system has a good potential for providing precision hover load placement and flight with unstable loads.

Figure 41. AAELSS II installed on CH-47 helicopter.

REMOTELY PILOTED VEHICLES

AQUILA – The AQUILA Remotely Piloted Vehicle (RPV) Program is being funded through the Weapon System Manager at AVSCOM and contracted with the Lockheed Missiles and Space Company through AMRDL. This RPV system will enable the TRADOC to evaluate the capabilities of mini-RPVs through "hands on" testing so that a ROC can be established if warranted.

This is the first Army program utilizing a Letter of Agreement (LOA) management structure between the developer and user commands. Figure 42 depicts an AQUILA RPV mounted on its pneumatic catapult launcher.

First flight of an AQUILA RPV occurred in December 1975. Six test flights were accomplished with the first RPV using tricycle landing gear for wheeled takeoff and landing. In January 1976 flight-test operations transferred to Ft. Huachuca, Arizona, for tests of the full flight configuration of the AQUILA system. From January through April 1976, seven test-flights of the AQUILA were made resulting in a loss of six of the RPVs. These losses were caused by separate and unrelated failures. In May 1976 flight-test activities were suspended to allow for complete program reliability review by the Contractor and the Government. In August 1976, following implementation of several program and system modifications, ground tests and simulations, and an Army flightworthiness review, reactivation of flight-test activities was authorized. Testing resumed in August and following a launch incident and a flight accident the recovery system was changed from a horizontal net to a vertical net arrangement. A successful flight and radio control recovery was achieved with this new recovery system in early October.

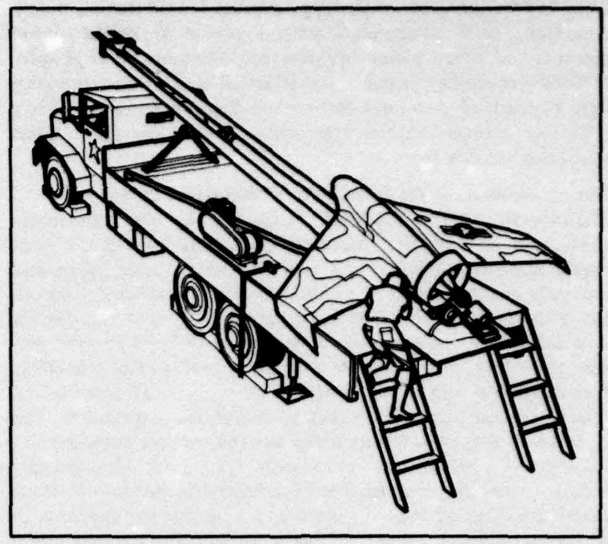

Figure 42. AQUILA RPV mounted on pneumatic catapult launcher.

HELICOPTER ICE PROTECTION

A helicopter ice protection program was initiated in July 1973 for the development of an advanced anti/deicing system for Army helicopters, present and future. This R&D effort has resulted in the establishment of meteorological design criteria applicable to both military and commercial helicopters and the determination that rotor blade ice protection for Army helicopters can only be met with advanced technology concepts. An advanced cyclic, electrothermal concept was designed and installed on a UH-1H test helicopter for engineering icing flight test purposes. During the winters of 1975-1976, the test helicopter was subjected to simulated icing tests, using the AEFA helicopter icing simulation system (HISS) and the Ottawa (Canada) spray rig. The ice protected UH-1H test aircraft is shown in figure 43 while hovering in the Ottawa Spray Rig. These tests were conducted to optimize rotor deicing system control parameters and demonstrate proper ice shedding characteristics. A total of 7 hours flight test time was accumulated in the Ottawa Spray Rig. Test conditions included the full spectrum of icing severity, including a temperature range of 0° C to −20° C and cloud liquid water content of 0.25 gm/m^3 to 0.80 gm/m^3. During these tests, preliminary evaluations of the engine IR suppressor and the M-200 (2.75 mm) rocket system were conducted. These tests have demonstrated conceptual feasibility and the test UH-1H was cleared for conduct of natural icing tests. Results of trade-off analyses, to quantify system penalties such as gross weight, payload, performance, reliability, maintainability and cost were coordinated with TRADOC and a joint DARCOM/TRADOC position regarding the helicopter ice protection requirement, acceptability of penalties and courses of action were established. Coordination efforts were initiated with the USAF Air Weather Service to improve icing forecasting techniques and accuracy and with the FAA to assist in the implementation of civil helicopter ice protection system legislation.

IN-FLIGHT SIMULATOR

A simulation control system is being developed to be used in both ground-based and in-flight simulators, which can vary aircraft stability characteristics and simulate various guidance and control display concepts. The in-flight simulator results from a modification of a system previously developed by NASA at the Ames

Figure 43. Ice-protected UH-1H helicopter in Ottawa spray rig.

Research Center, designated V/STOLAND, and is being installed in a UH-1H helicopter. The hardware has been delivered and dynamic acceptance tests have been performed on the ground fixed-base simulator. Installation in the UH-1H is almost complete. Following flight acceptance tests and initial shakedown tests, the in-flight simulator will be used to verify certain ground-base simulator results.

LABORATORY SUPPORT ACTIONS – PROJECT/PRODUCT MANAGERS AND OPERATIONAL SYSTEMS

ADVANCED TECHNOLOGY ENGINES

The Laboratory has provided the UTTAS PM technical support for the development of the T700-GE-700 engine through MQT, figure 44. The T-700 powers both UTTAS and AAH aircraft as well as commercial derivatives of the UTTAS by both Sikorsky and Boeing Vertol airframe companies. The T-700 is a direct outgrowth of the AMRDLs 1500 SHP Demonstrator Engine Program. Since initiation of development testing in February 1973, the engine has accumulated over 26,000 test hours of which over 9,000 hours were development testing (test cell) and over 17,000 hours were generated by production testing and aircraft field test.

HEAVY LIFT HELICOPTER

On 1 August 1975 a Stop Work Order was issued to the Boeing Vertol Company to stop all work on the HLH Program except for certain exceptions listed in the order. On 3 October 1975, the

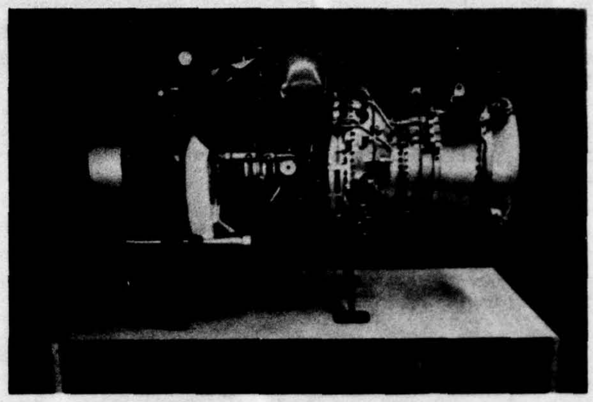

Figure 44. T-700 Advanced Technology Engine.

program was officially terminated. As a result, the HLH Project Office at the Eustis Directorate which had technical responsibility for most of the program was disbanded. However, as a part of the program termination plan AMRDL has the responsibility for the review and publication of all outstanding technical reports.

ADVANCED SCOUT HELICOPTER

AMRDL continued to supply parametric and preliminary aircraft design configuration and performance data for the conceptual phase of the ASH systems acquisition cycle to the ASH Project Manager (PM) and to appropriate ASH study groups. These studies included further examination of the characteristics of DOD inventory aircraft derivatives to permit determination of their cost-effectiveness relative to new development and commercial off-the-shelf aircraft. Performance and weight data of the inventory aircraft with improved larger rotors and uprated engines were developed. The effects of advanced airfoils on the rotor diameter and performance of the OH-58A were also assessed. New development designs were developed to illustrate the impact of concurrent or later technology versions of the Light Attack Helicopter (LAH) and Light Utility Helicopter (LUH), and current versus advanced engine technology for twin ASH, LUH and LAH variants. ASH and LAH designs based on the ABC principle were also developed against ASH RFP requirements. In addition, AMRDL supported an extensive evaluation of human engineering design requirements for the ASH. The overall effort was managed and reported by the U.S. Army Human Engineering Laboratory.

ACTIVITY INDICATORS

PUBLICATIONS

During FY76/7T, AMRDL originated a total of 279 reports, papers, and presentations. The total number of reports was 135 of which 73 were prepared (entirely or in part) by AMRDL employees and 62 were published under contracts. Reports which originated at Ames, Langely, or Lewis Directorates bear NASA report numbers, while those originated at Eustis Directorate bear AMRDL numbers. A complete listing of these publications and presentations is contained in Appendix B.

HONORS AND AWARDS

Mr. Bernard L. Karp, Eustis Directorate, received a special "Letter of Commendation" from Brigadier General William I. Rolya, 330th Army Security Agency Company, for assisting unit maintenance personnel in applying the AMRDL developed field fix to RU-21H (Guardrail) aircraft mission antennas. Mr. Karp provided technical assistance to the ASA Company maintenance personnel and his personal coordination with the host Air Force command to acquire necessary support resulted in successful application of the antenna fix and expedient returning of the Guardrail System to a mission ready status.

Dr. William Ballhaus and Francis Caradonna, Research Scientists, have been selected for consideration to receive the Army R&D Achievement Award for their contribution to the Army's airmobile concept by development of computational techniques enabling the analyses of adverse transonic effects encountered by helicopter rotors at high forward speeds.

Dr. Robert Ormiston, Dr. Dewey Hodges, and William Bousman were recipients of a NASA-Ames Research Center Technology Utilization Award for their contributions toward the improvement of hingeless rotor stability.

Dr. William McCroskey was selected by the American Society of Michigan Engineers as the Freeman Scholar for 1976 for his critical review on the subject "Current Research in Unsteady Fluid Dynamics."

Dr. William McCroskey received the Outstanding Engineer Award from the San Francisco Section of the American Institute of Aeronautics and Astronautics.

Dr. Fredric Schmitz and Donald Boxwell were awarded a Certificate of Outstanding Achievement and medallion for their paper entitled "In Flight Far Field Measurement of Helicopter Impulsive Noise" at the 1976 Army Science Conference.

Mr. Kent Smith, Eustis Directorate, received a Special Act Award pertaining to his combined cost savings associated with contractual execution and performance above and beyond the established grade. As a result of the savings, Mr. Smith has been nominated for Presidential recognition by the Fort Eustis Incentive Awards Committee.

National Aeronautics and Space Administration presented the Group Achievement Award to Refan Project Team for outstanding contributions to the reduction of aircraft noise in the vicinity of airports. Member George A. Bobula, Lewis Directorate, received his award 18 December 1975.

Four members of the Ft. Eustis engineering staff were recently presented the Army's R&D Achievement Award for work on special bearings for use in helicopters. The four, J. Nelson Daniel, Leonard M. Bartone, John W. Sobczak and Rouzee Givens, were presented the award by Maj. Gen. Philip R. Feir, assistant chief of staff for Army Research, Development and Acquisition. The quartet's work led to the development of laminated pad elastomeric bearings. Savings in the life cycle of the bearings for a fleet of 1,000 aircraft is estimated at $12 million to $20 million. The bearings are thin alternating layers of elastomer and metal shims which support high compression loads such as the force of rotating helicopter blades.

PATENTS

Mr. Salvatore J. Grisaffe and Mr. Stanley R. Levine of the Lewis Directorate received patent number 3,931,447 for their development of fused silicide coatings containing discrete particles for protecting Niobium alloys.

Dr. Robert Ormiston and Dr. Dewey Hodges of the Ames Directorate have applied for a patent "Hingeless Rotor with Improved Stability."

OTHER ACTIVITIES

Major General Eivind H. Johansen, Commanding General, U.S. Army Aviation Systems Command, visited the Ames Research Center for a briefing on AMRDL operations and programs and for a tour of NASA facilities (figure 45).

AMRDL hosted the Winter Meeting of the Army Scientific Advisory Panel at Ames Research Center in February, 1976. Over eighty distinguished panel members and guests were in attendance which included the Honorable Edward A. Miller, Assistant Secretary of the Army (R&D) and General John R. Deane, Jr., Commanding General of the U.S. Army Materiel Development and Readiness Command. The extremely successful meeting focused on requirements and achievements in airmobility for the US Army.

The American Helicopter Society national and regional officers include the following AMRDL personnel:

Figure 45. Major General Eivind H. Johansen (L) discusses the joint NASA/Army Tilt Rotor Research Aircraft with Dr. Richard M. Carlson, AMRDL Director, and Lieutenant Colonel James H. Brown, Jr., Deputy Manager, Test and Simulation, Ames Directorate.

Dr. Richard M. Carlson – Director at Large
Andrew W. Kerr – Western Region Vice President
Frederick H. Immen – Western Region Director

AMRDL is well represented on governmental and nongovernmental, technical and scientific committees of both national and international stature. The following is a listing of the organizations in which employees of the Laboratory participate as officers and/or members (a complete listing of committees, affiliation, individuals and AMRDL element is presented in Appendix C):

- American Helicopter Society
- American Institute of Aeronautics and Astronautics
- American Mathematical Society
- American Society of Civil Engineers
- American Society of Mechanical Engineers
- Defense Atomic Support Agency
- Department of Defense
- Department of Army
- Department of the Navy
- National Aeronautics and Space Administration
- National Research Council
- North Atlantic Treaty Organization
- Society of Aeronautical Weight Engineers
- Society of Automotive Engineers
- Subsonic Aerodynamic Testing Association
- U.S. Civil Service Commission

SPECIAL ITEM

Laboratory Director – Dr. Richard M. Carlson was named Director of the U.S. Army Air Mobility Research and Development Laboratory on 20 November 1975. Dr. Carlson was Chief of the Advanced Systems Research Office and Acting Director prior to being named Director.

A 27-year veteran in the field of research, development, design and evaluation of helicopters, Dr. Carlson joined the Laboratory in January 1972 as Chief of the Advanced Systems Research Office. Prior to this, he was Division Engineer for Rotary Wing Advanced Design, Lockheed-California Company.

The new Director received his Bachelor of Science and Master of Science Degrees in Aeronautical Engineering from the University of Washington, Seattle, in 1945 and 1948, and his PhD in Engineering Mechanics from Stanford University in 1960. He is a

Fellow of the Royal Aeronautical Society, an Honorary Fellow of the American Helicopter Society and an Associate Fellow of the Institute of Aeronautics and Astronautics. In addition, he is the first foreign member of the Swedish Society of Aeronautics and Astronautics, a member of Sigma Xi and a Registered Mechanical Engineer in the State of California.

Laboratory Deputy Director – On August 1, 1976, Colonel John B. Fitch became the Laboratory's new Deputy Director, succeeding Colonel Norman L. Robinson who retired from the Laboratory and from the U.S. Army following more than 30 years service. Colonel Robinson, who served as Deputy Director for four years, was the first person to hold that position following the reorganization of the Army aviation research laboratory in 1970.

The new Deputy Director is a Senior Army Aviator with over 2500 hr experience; he is a rated pilot in both fixed wing aircraft and helicopters and is a qualitative parachutist.

Colonel Fitch comes to his new post from the U.S. Army Training and Doctrine Command (TRADOC), Fort Monroe, Virginia where he served as Chief, Combat Air Systems, and Chief, Maneuver Division, Combat Developments, TRADOC.

A 1953 graduate of the U.S. Military Academy at West Point, N.Y., Colonel Fitch holds a Master of Science Degree in Aerospace Engineering, Georgia Institute of Technology and is a graduate of the U.S. Army Command and General Staff College.

FACILITIES

The facility complex available to the Laboratory is unique within the Government. It represents a special blending of both Army and NASA facilities which can be utilized to meet the R&D needs of the Army as well as the overall aviation community. The major facilities that are available to the Laboratory are indicated in Table IX.

TABLE IX. MAJOR FACILITIES AVAILABLE FOR R&D

- **Combustion research facility**
- **Component research lab**
- **Engine research facility**
- **Environmental test facility**
- **Flight research facilities**
- **Ground based simulation facilities**
- **Heat transfer facility**
- **ILLIAC IV**
- **Lunar lander facility**
- **Materials laboratory**
- **Structures research lab**
- **Structures testing lab**
- **Vulnerability testing laboratory**
- **Whirl tower facility**
- **Wind tunnels**
- **Acoustical test facility**
- **Cargo handling system integrated test rig**

Of the facilities indicated, those that impinge directly on current critical Army needs coupled with the Ames and Langley wind tunnels provides a balanced research base for a logical synthesis of aeronautical concept through evaluation. Specifically, the Ground Based Simulation Facilities are being utilized to study and evolve techniques for flying helicopters in the nap-of-the-earth environment. The Flight Simulator for Advanced Aircraft (FSAA) at the Ames Research Center is shown in figure 46.

Additional facilities that have become available or are being expanded to assist the R&D engineer in the advancement of the technology base are briefly described below.

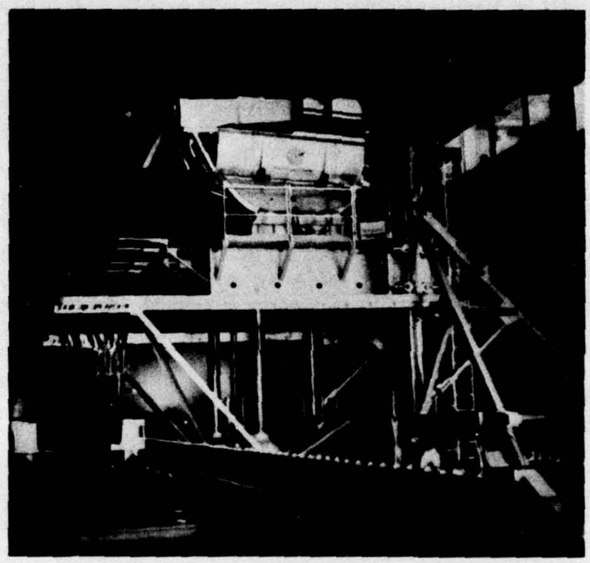

Figure 46. Flight Simulator for Advanced Aircraft.

COUNTERMEASURES TEST FACILITY

This test facility is located in the vicinity of the Research Support Area of Ft. Eustis, Virginia. Major items of equipment consist of engine test stand and associated equipment including water cooling tower. Specialized instrumentation equipment for support of engine test stand operation will perform read-out and recording of desired engine data during testing. Operation of infrared suppression devices will be supported by separate cooling air sources. Turboshaft engines will be required for use on the engine test stand and are on hand for immediate use. Microwave equipment will consist of transmitters and receivers necessary to generate and receive desired microwave frequencies and any supporting recording instrumentation. The microwave range will cover a 500 to 600 foot distance from the transmitting station for the location of test specimens. Visual detection support will require an area for build-up of glint mock-ups and evaluations. Any future laser countermeasures testing will require additional pre-fab buildings to house and secure laser testing equipment.

BALLISTIC PROTECTION RESEARCH TEST FACILITY

Ballistic Research Test Facilities, an indoor/outdoor R&D range and a larger more remote full-scale ballistic range to provide testing of ground operational aircraft, have been provided to develop design criteria for survivability enhancement of Army aircraft and aircraft system/components against threats ranging from small arms projectiles (7.62 mm and 0.30 caliber) up to and including small high explosive projectiles (23 mm).

The indoor/outdoor range is approximately 150 ft by 50 ft. Small scale/component testing is done with a 25 ft by 50 ft building using projectiles up to 0.50 caliber. The building contains an armored specimen room, instrumentation and work areas. Larger specimen and hazardous materials are tested outdoors, where projectiles up to 23 mm API are fired into a concrete block, earth filled and covered bunker. A sophisticated instrumentation and compact computerized data retrieval/recording system (figure 47) using the latest high level basic-language interaction, tape memory with graphic printer, display and storage capability to interpret, forecast, spot costly errors and analyze data in a very short time was installed as a part of the test facilities improvements.

The remote facility is used for full scale ballistic testing of ground operating aircraft under dynamic conditions. A tie-down pad, 100 ft by 100 ft, is bordered on three sides by a thirty foot high earthen berm. Aircraft are secured to the pad and operated at flight conditions for testing of selected components under realistic conditions. Threats up to 23 mm HEI-T are used. A trailer protected by a concrete/earth wall contains facilities for firing the weapon, monitoring the test and recording data. The entire facility is bordered by a security fence 400 ft by 400 ft.

NONDESTRUCTIVE TESTING FACILITY

The Eustis Directorate has received direction from AVSCOM to become the NDT center for Army aviation. This center will provide NDT support to all aspects of research, development, manufacturing and fleet operation for Army aircraft. Initial equipment acquisitions include X-ray, neutron radiography, acoustic holography, and image enhancement equipment, while long range plans call for the acquistion of all relevant NDT equipment.

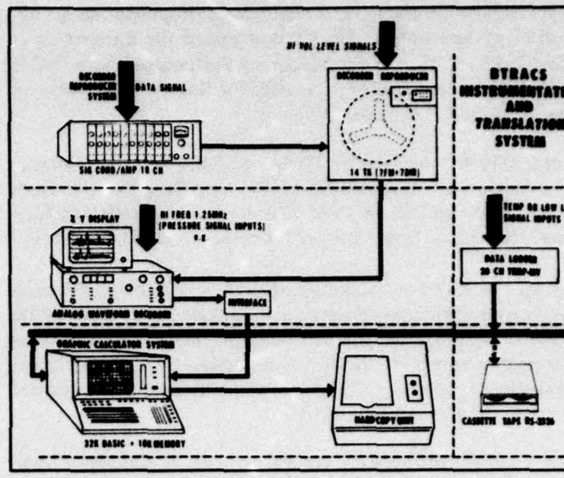

Figure 47. BTRACS instrumentation and translation system schematic.

Acoustical holography provides a method to visually observe the interior properties of solids. This acoustical technique employs high frequency sound (ultrasound) to obtain three-dimensional information on the internal structure of the material under examination. The acoustical hologram is the converter or recorder which allows acoustic information to be visualized much as film is the converter or recorder for light. Acoustical holograms may be thought of as windows through which we are observing the interior properties of the materials being inspected.

APPENDIX A
AMRDL PROGRAM STRUCTURE

CATEGORY	6.1 RESEARCH Project - Tech Area Title Funds: Amount*-%** of 6.1 for 76/7T	6.2 EXPLORATORY DEVELOPMENT Project - Tech Area Title Funds: Amount*-%** of 6.2 for 76/7T	6.3 ADVANCED DEVELOPMENT Project - Project - Task Title Funds: Amount*-%** of 6.3 for 76/7T
FLIGHT DYNAMICS	**1F161102AH45-TAI** **Rsch in Aerodynamics** *2490/655 - 51%/48%*	**1F262209AH76-TAI** **Aerodynamics Technology** *222[illegible]/615 - 14%/14%*	**1F263211D157-Task 11 & 12** **Advanced Rotor Tech** *1299/752 - 8%/21%*
VEHICLE DESIGN	**1F161102AH45-TAII** **Rsch in Propulsion** *1115/296 - 23%/22%* **1F161102AH45-TAIII** **Rsch in Structures** *1125/328 - 23%/25%*	**1F161102AH76-TAII** **Structures Technology** *2303/600 - 14%/14%* **1F161102AH76-TAIII** **Propulsion Technology** *2865/814 - 18%/18%* **1F161102AH76-TAIV** **Reliability & Maintainability** *1616/508 - 10%/11%* **1F161102AH76-TAVIII** **Aircraft Subsystems** *740/95 - 4%/2%*	**1F263211DB41** **Advanced Aircraft Structures** *1427/795 - 9%/22%* **1G263201D447** **Demonstrator Engines** *977/470 - 6%/13%* **1G263201DB72** **Propulsion Components** *100/105 - 1%/3%* **1F263209DB38** **Reliability & Maintainability** *909/130 - 6%/3%*
MILITARY APPLICATION		**1F161102AH76-TAV** **Safety & Survivability** *2221/596 - 14%/13%* **1F161102AH76-TAVI** **Mission Support** *912/357 - 6%/8%* **1F161102AH76-TAIX** **Remotely Piloted Vehicles** *649/91 - 4%/2%* **1F262201DH96** **Aircraft Weapons Technology** *1600/500 - 10%/11%*	**1F263209DB33** **Cargo Handling Equipment** *354/130 - 2%/3%*
SUPPORT	**1F161102AH45-TAIV** **Mathematics** *70/21 - 1%/2%* **ILIR (Lab Indep Rsch)** *100/35 - 2%/3%*	**1F161102AH76-TAVII** **Aircraft Systmes Synthesis** *1069/294 - 6%/7%*	
ADVANCED TECHNOLOGY DEMONSTRATION			**1F263213DB36** **Rotor System Rsch Aircraft** *4606/0 - 30%/0%* **1F263212DB74** **Tilt Rotor Aircraft** *3315/900 - 21%/25%* **1F263211D157-Task 17** **Advancing Blade Concept** *2556/358 - 17%/10%*

*In Thousands

**Percentages of AMRDL R&D funds allotted to each identified Project/Tech Area/Task level as applied to total of either 6.1, 6.2 or 6.3 AMRDL R&D funds.

APPENDIX B
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APPENDIX D
LIST OF ABBREVIATIONS

AAH	Advanced Attack Helicopter
AALESS	Active Arm Load Stabilization System
AAWS	Advanced Aerial Weapons System
ABC	Advancing Blade Concept
ADI	Alternating Direction Implicit
AEFA	Aviation Engineering Flight Activity
AGARD	Advisory Group for Aerospace Research and Development
AMRDL	(US Army) Aviation Mobility Research and Development Laboratory
ANP	Annual Narrative Program
API	Armor-Piercing Incendiary
APU	Auxiliary Power Unit
ARMCOM	(US Army) Armament Command
ARMS	Aircraft Reliability and Maintainability Simulation
ARPA	Advanced Research Project Agency
ASA	Army Security Agency
ASE	Aircraft Survivability Equipment
ASH	Advanced Scout Helicopter
ASRO	Advanced Systems Research Office
ASTD	Advanced Structures Technology Demonstrator
ATDE	Advanced Technology Demonstrator Engine
AUTOCUE	Automatic Target Cueing System
AVLABS	(US Army) Aviation Materiel Laboratories
AVSCOM	(US Army) Aviation Systems Command
BIU	Battery Interface Unit
BMR	Bearingless Main Rotor
BTRACS	Ballistic Test Range Aircraft Survivability
C	Centigrade
CAD-E	Computer Aided Design and Engineering
CHD	Container Handling Device
COEA	Cost and Operational Effectiveness Analysis
CONUS	Continental United States
CTR	Controllable Twist Rotor
DA	Department of the Army
DARCOM	(US Army) Materiel Development and Readiness Command
dB	Decibel
dc	Direct Current
DCSOPS	Deputy Chief of Staff for Operations and Plans
DOD	Department of Defense
ECW	Electroform Conductive Wax
E&S	Engineer and Scientist
FAA	Federal Aviation Administration
FCS	Flight Control System
FLIR	Forward Looking Infrared
FORSCOM	(US Army) Forces Command
FSAA	Flight Simulator for Advanced Aircraft
ft	Feet
FY	Fiscal Year
g	Gravity
gm	Gram
GS	General Schedule (Grade Level)
HEI	High Explosive Incendiary
HEI-T	High Explosive Incendiary-Tracer
HELLCOM	Helicopter Commonality Review
HISS	Helicopter Icing Spray System
HLH	Heavy Lift Helicopter
HP	Horsepower
HQ	Headquarters
HYSAS	Hydrofluidic Stability Augmentation System
IFR	Instrument Flight Rules
IGE	In-Ground Effect
IOC	Initial Operational Capability
IR	Infrared
JTCC	Joint Technical Coordinating Committee
ksi	Pounds Per Square Inch (Thousands)
kW	Kilowatt
LAH	Light Attack Helicopter
lb	Pound
LLNO	Low Level Night Operation
LOA	Letter of Agreement
LOGMOD	Logic Model
LUH	Light Utility Helicopter
m^3	Cubic Meter
mm	Millimeter
MBO	Management By Objectives
MCTR	Multicycle CTR
MERADCOM	(US Army) Mobility Equipment Research and Development Command
MICOM	(US Army) Missile Command
MMAS	Mini-Manned Aircraft System
MM&T	Manufacturing Methods and Technology
MOU	Memorandum of Understanding
MQT	Material Qualification Test
MRB	Main Rotor Blade
MTBF	Mean Time Between Failure
MTS	Multi-Tubular Spar
NASA	National Aeronautics and Space Administration
NASTRAN	NASA Structures Analysis
NATO	North Atlantic Treaty Organization
NDT	Nondestructive Testing
NiCad	Nickel-Cadmium
NOE	Nap-of-the-Earth
OMA	Operation and Maintenance, Army
OPR	Objectives, Priority and Rationale
PEMA	Procurement of Equipment and Missiles, Army
PIO	Pilot Induced Oscillation
PM	Project/Product Manager
PRAM (U	(US Air Force) Program Office for RAM
PSDE	Preliminary Systems Design Engineering
psi	Pounds per Square Inch
R&D	Research and Development
R&M	Reliability and Maintainability

RAM	Reliability, Availability and Maintainability
RCS	Radar Cross Section
RDM	Rotor Dynamics Model
RDT&E	Research, Development, Test, and Engineering
RFP	Request for Proposal
RFQ	Request for Quote
RIO	Return on Investment
ROC	Required Operational Capability
rpm	Revolutions Per Minute
RPV	Remotely Piloted Vehicle
RSRA	Rotor System Research Aircraft
RTA	Rotor Test Apparatus
sec	Second
SFC	Specific Fuel Consumption
SHP	Shaft Horsepower
SOR	Successive Over-Relaxation
SPEF	Single Program Element Funding
SPF	Single Project Funding
SRIO	Systems Research Integration Office
SSEB	Source Selection Evaluation Board
STAGG	Small Turbine Advanced Gas Generator
STOG-77	Science and Technology Objectives Guide – 1977 (Confidential)
SUR/VTOL	Surveillance/Vertical Takeoff and Landing Aircraft System
TILO	Technical Institute Liaison Office
TIMS	The Institute of Management Sciences
TMI	Terrain Management Institute
TRADOC	(US Army) Training and Doctrine Command
TRADS	Transportation Research and Development Support
TRADSCOM	Transportation Research and Development Command
TRASANA	TRADOC Systems Analysis Activity
TRECOM	Transportation Research and Engineering Command
USAF	United States Air Force
UTTAS	Utility Tactical Transport Aircraft System
VR	Vulnerability Reduction
V/STOL	Vertical/Short Takeoff and Landing
V/STOLAND	V/STOL Advanced Autopilot System